LELAND·STANFORD·JVNIOR·VNIVERSITY

PROCEEDINGS

OF THE

ROYAL SOCIETY OF LONDON.

From January 18 to April 26, 1894.

VOL. LV.

CONTENTS.

VOL. LV.

—••‡‡•‡‡•••—

Page

Note on some Changes in the Blood of the General Circulation consequent upon certain Inflammations of an acute local character. By C. S. Sherrington, M.D., F.R.S., Lecturer of Physiology, St. Thomas's Hospital, Professor-Superintendent of the Brown Institution, London. [Plate 1] 161

No. 333.—*March* 1, 1894.

March 8, 1894.

March 15, 1894.

No. 334.—*April* 19, 1894.

April 26, 1894.

PROCEEDINGS

OF

THE ROYAL SOCIETY

~~~~~~~~~~~~~~~~~~~~~~~~~

January 18, 1894.

The LORD KELVIN, D.C.L., LL.D., President, followed by Sir
JOHN EVANS, K.C.B., D.C.L., LL.D., Vice-President and
Treasurer, in the Chair.

The Right Hon. James Bryce was admitted into the Society.

A List of the Presents received was laid on the table, and thanks
ordered for them.

The following Papers were read :—

I. "On Homogeneous Division of Space."   By LORD KELVIN,
P.R.S.   Received January 17, 1894.

§ 1. The homogeneous division of any volume of space means the
dividing of it into equal and similar parts, or cells, as I shall call them,
all sameways oriented.   If we take any point in the interior of one cell
or on its boundary, and corresponding points of all the other cells,
these points form a homogeneous assemblage of single points, accord-
ing to Bravais' admirable and important definition.*   The general
problem of the homogeneous partition of space may be stated thus :—
Given a homogeneous assemblage of single points, it is required to
find every possible form of cell enclosing each of them subject to the
condition that it is of the same shape and sameways oriented for all.
An interesting application of this problem is to find for a crystal
(that is to say, a homogeneous assemblage of groups of chemical
atoms) a homogeneous arrangement of partitional interfaces such
that each cell contains all the atoms of one molecule.   Unless we

---

* 'Journal de l'École Polytechnique,' tome 19, cahier 33, pp. 1—128 (Paris,
1850), quoted and used in my 'Mathematical and Physical Papers,' vol. 3, art. 97,
p. 400.

VOL. LV.   B

knew the exact geometrical configuration of the constituent parts of the group of atoms in the crystal, or crystalline molecule as we shall call it, we could not describe the partitional interfaces between one molecule and its neighbour.

Knowing as we do know for many crystals the exact geometrical character of the Bravais assemblage of corresponding points of its molecules, we could not be sure that any solution of the partitional problem we might choose to take would give a cell containing only the constituent parts of one molecule. For instance, in the case of quartz, of which the crystalline molecule is probably $3(SiO_2)$, a form of cell chosen at random might be such that it would enclose the silicon of one molecule with only some part of the oxygen belonging to it, and some of the oxygen belonging to a neighbouring molecule, leaving out some of its own oxygen, which would be enclosed in the cell of either that neighbour or of another neighbour or other neighbours.

§ 2. This will be better understood if we consider another illustration—a homogeneous assemblage of equal and similar trees planted close together in any regular geometrical order on a plane field either inclined or horizontal, so close together that roots of different trees interpenetrate in the ground, and branches and leaves in the air. To be perfectly homogeneous, every root, every twig, and every leaf of any one tree must have equal and similar counterparts in every other tree. So far everything is natural, except, of course, the absolute homogeneousness that our problem assumes; but now, to make a homogeneous assemblage of molecules in space, we must suppose plane above plane each homogeneously planted with trees at equal successive intervals of height. The interval between two planes may be so large as to allow a clear space above the highest plane of leaves of one plantation and below the lowest plane of the ends of roots in the plantation above. We shall not, however, limit ourselves to this case, and we shall suppose generally that leaves of one plantation intermingle with roots of the plantation above, always, however, subject to the condition of perfect homogeneousness. Here, then, we have a truly wonderful problem of geometry—to enclose ideally each tree within a closed surface containing every twig, leaf, and rootlet belonging to it, and nothing belonging to any other tree, and to shape this surface so that it will coincide all round with portions of similar surfaces around neighbouring trees. Wonderful as it is, this is a perfectly easy problem if the trees are given, and if they fulfil the condition of being perfectly homogeneous.

In fact we may begin with the actual bounding surface of leaves, bark, and roots of each tree. Wherever there is a contact, whether with leaves, bark, or roots of neighbouring trees, the areas of contact form part of the required cell-surface. To complete the cell-surface we

have only to swell out* from the untouched portions of surface of each tree homogeneously until the swelling portions of surface meet in the interstitial air spaces (for simplicity we are supposing the earth removed, and roots, as well as leaves and twigs, to be perfectly rigid). The wonderful cell-surface which we thus find is essentially a case of the tetrakaidekahedronal cell, which I shall now describe for any possible homogeneous assemblage of points or molecules.

§ 3. We shall find that the form of cell essentially consists of fourteen walls, plane or not plane, generally not plane, of which eight are hexagonal and six quadrilateral; and with thirty-six edges, generally curves, of meeting between the walls; and twenty-four corners where three walls meet. A cell answering this description must of course be called a tetrakaidekahedron, unless we prefer to call it a fourteen-walled cell. Each wall is an interface between one cell and one of fourteen neighbours. Each of the thirty-six edges is a line common to three neighbours. Each of the twenty-four corners is a point common to four neighbours. The old-known parallelepipedal partitioning is merely a very special case in which there are four neighbours along every edge, and eight neighbours having a point in common at every corner. We shall see how to pass (§ 4) continuously from or to this singular case, to or from a tetrakaidekahedron differing infinitesimally from it; and, still continuously, to or from any or every possible tetrakaidekahedronal partitioning.

§ 4. To change from a parallelepipedal to a tetrakaidekahedronal cell, for one and the same homogeneous distribution of points, proceed thus :—Choose any one of the four body-diagonals of a parallelepiped and divide the parallelepiped into six tetrahedrons by three planes each through this diagonal, and one of the three pairs of parallel edges which intersect it in its two ends. Give now any purely translational motion to each of these six tetrahedrons. We have now the 4×6 corners of these tetrahedrons at twenty-four distinct points. These are the corners of a tetrakaidekahedron, such as that described generally in § 3. The two sets of six corners, which before the movement coincided in the two ends of the chosen diagonal, are now the corners of one pair of the hexagonal faces of the tetrakaidekahedron. When we look at the other twelve corners we see them as corners of other six hexagons, and of six parallelograms, grouped together as described in § 15 below. The movements of the six tetrahedrons may be such that the groups of six corners and of four corners are in fourteen planes as we shall see in § 14; but, if they are made at random, none of the groups will be in a single plane. The fourteen faces, plane or not plane, of the tetrakaidekahedron are obtained by drawing arbitrarily any set of surfaces to constitute four of the hexagons and three of the quadrilaterals, with arbitrary curves for the edges between hexagon and

* Compare 'Mathematical and Physical Papers,' vol. 3, art. 97, § 5.

hexagon and between hexagons and quadrilaterals, and then by drawing parallel equal and similar counterparts to these surfaces in the remaining four hexagonal and three quadrilateral spaces in the manner more particularly explained in § 6 below. It is clear, or at all events I shall endeavour to make it clear by fuller explanations and illustrations below, that the figure thus constituted fulfils our definition (§1) of the most general form of cell fitted to the particular homogeneous assemblage of points corresponding to the parallelepiped with which we have commenced. This will be more easily understood in general, if we first consider the particular case of *parallelepipedal* partitioning, and of the deviations which, without altering its corners, we may arbitrarily make from a plane-faced parallelepiped, or which we may be compelled by the particular figure of the molecule to make.

§ 5. Consider, for example, one of the trees of § 2, or if you please a solid of less complex shape, which for brevity we shall call S, being one of a homogeneous assemblage. Let P be a point in unoccupied space (air, we shall call it for brevity), which, for simplicity we may suppose to be somewhere in the immediate neighbourhood of S, although it might really be anywhere far off among distant solids of the assemblage. Let PA, PB, PC be lines parallel to any three Bravais rows not in one plane, and let A, B, C be the nearest points corresponding to P in these lines. Complete a parallelepiped on the lines PA, PB, PC, and let QD, QE, QF be the edges parallel to them

(FIG. 7, OF § 9.)

through the opposite corner Q. Because of the homogeneousness of the assemblage, and because A, B, C, D, E, F, Q are points corresponding to P, which is in air, each of those seven points is also in air. Draw any line through air from P to A and draw the lines of corresponding points from B to F, D to Q, and C to E. Do the same relatively to PB, AF, EQ, CD; and again the same relatively to

PC, AE, FQ, BD. These twelve lines are all in air, and they are the edges of our curved-faced parallelepiped. To describe its faces take points infinitely near to one another along the line PC (straight or curved as may be) : and take the corresponding points in BD. Join these pairs of corresponding points by lines in air infinitely near to one another in succession. These lines give us the face PBDC. Corresponding points in AE, FQ, and corresponding lines between them give us the parallel face AFQE. Similarly we find the other two pairs of the parallel faces of the parallelepiped. If the solids touch one another anywhere, either at points or throughout finite areas, we are to reckon the interface between them as air in respect to our present rules.

§ 6. We have thus found the most general possible parallelepipedal partitioning for any given homogeneous assemblage of solids. Precisely similar rules give the corresponding result for *any possible partitioning* if we first choose the twenty-four corners of the tetrakaidekahedron by finding six tetrahedrons and giving them arbitrary translatory motions according to the rule of § 4. To make this clear it is only now necessary to remark that the four corners of each tetrahedron are essentially corresponding points, and that if one of them is in air all of them are in air, whatever translatory motion we give to the tetrahedron.

§ 7. The transition from the parallelepiped to the tetrakaidekahedron described in § 4 will be now readily understood, if we pause to consider the vastly simpler two-dimensional case of transition from a parallelogram to a hexagon. This is illustrated in figs. 1 and 2; with heavy lines in each case for the sides of the hexagon, and light lines for the six of its diagonals which are sides of constructional triangles. The four diagrams show different relative positions in one plane of two equal homochirally similar triangles ABC, A'B'C'; oppositely

<p align="center">FIG. 1.</p>

Fig. 2.

oriented (that is to say, with corresponding lines AB, A'B' parallel but in inverted directions). The hexagon AC'BA'CB', obtained by joining A with B' and C', B with C' and A', and C with A' and B', is clearly in each case a proper cell-figure for dividing plane space homogeneously according to the Bravais distribution of points defined by either triangle, or by putting the triangles together in any one of the three proper ways to make a parallelogram of them. The corresponding operation for three-dimensional space is described in § 4: and the proof which is obvious in two-dimensional space is clearly valid for space of three dimensions, and therefore the many words which would be required to give it formal demonstration are superfluous.

§ 8. The principle according to which we take arbitrary curved surfaces with arbitrary curved edges of intersection, for seven of the faces of our partitional tetrakaidekahedron, and the other seven correspondingly parallel to them, is illustrated in figs. 3, 4, 5, and 6, where the corresponding thing is done for a partitional hexagon suited to the homogeneous division of a plane. In these diagrams the hexagon is for simplicity taken equilateral and equiangular. In drawing fig. 3, three pieces of paper were cut, to the shapes *kl*, *mn*, *uv*. The piece *kl* was first placed in the position shown relatively to AC', and a portion of the area of one cell to be given to a neighbour across the frontier C'A on one side was marked off. It was then placed in the position shown relatively to A'C and the equivalent portion to be taken from a neighbour on the other side was marked. Corresponding give-and-take delimitations were marked on the frontiers C'B and B'C, according to the form *mn*; and on the frontiers BA', AB', according to the form *uv*. Fig. 4 was drawn on the same plan

Fig. 3.

Fig. 4.

but with one pair of frontiers·left as straight lines, and the two other pairs drawn by aid of two paper templets. It would be easy, but not worth the trouble, to cut out a large number of pieces of brass of the shapes shown in these diagrams and to show them fitted together like the pieces of a dissected map. Figs. 5 and 6 are drawn on the same principle; fig. 6 showing, on a reduced scale, the result of putting pieces together precisely equal and similar to that shown in

Fig. 5.

fig. 5. In these diagrams, unlike the cases represented in figs. 3 and 4, the primitive hexagon is, as shown clearly in fig. 5, divided into isolated parts. But if we are dealing with homogeneous division of solid space, the separating channels shown in fig. 5 might be sections, by the plane of the drawing, of perforations through the matter of one cell produced by the penetration of matter, rootlets for example, from neighbouring cells.

§ 9. Corresponding to the three ways by which two triangles can be put together to make a parallelogram, there are seven, and only seven, ways in which the six tetrahedrons of § 4 can be put together to make a parallelepiped, in positions parallel to those which they had in the original parallelepiped. To see this, remark first that among the thirty-six edges of the six tetrahedrons seven different lengths are found which are respectively equal to the three lengths of edges (three quartets of equal parallels); the three

FIG. 6.

lengths of face-diagonals having ends in P or Q (three pairs of equal parallels); and the length of the chosen body-diagonal PQ. (Any one of these seven is, of course, determinable from the other six if given.)

In the diagram, fig. 7, full lines show the edges of the primitive parallelepiped, and dotted lines show the body-diagonal PQ and two pairs of the face-diagonals, the other pair of face-diagonals (PF, QC), not being marked on the diagram to avoid confusion. Thus, the diagram shows, in the parallelograms QDPA and QEPB, two of the three cutting planes by which it is divided into six tetrahedrons, and it so shows also two of the six tetrahedrons, QPDB and QPEA. The lengths QP, QD, QE, QF are found in the edges of every one of the six tetrahedrons, the two other edges of each being of two of the three 'engths QA, QB, QC. The six tetrahedrons may be taken in order of

Fig. 7.

three pairs having edges of lengths respectively equal to QB and QC, QC and QA, QA and QB. It is the third of these pairs that is shown in fig. 7. Remark now that the sum of the six angles of the six tetrahedrons at the edge equal to any one of the lengths QP, QD, QE, QF is four right angles. Remark also that the sum of the four angles at the edge of length QA in the two pairs of tetrahedrons in which the length QA is found is four right angles, and the same with reference to QB and QC. Remark lastly that the two tetrahedrons of each pair are equal and dichirally* similar, or enantio-morphs as such figures have been called by German writers.

§ 10. Now, suppose any one pair of the tetrahedrons to be taken away from their positions in the primitive parallelepiped, and, by purely translational motion, to be brought into position with their edges of length QD coincident, and the same to be done for each of the other two pairs. The sum of the six angles at the coincident edges being two right angles, the plane faces at the common edge will fit together, and the condition of parallelism in the motion of each pair fixes the order in which the three pairs come together in the new position, and shows us that in this position the three pairs form a parallelepiped essentially different from the primitive paral-lelepiped, provided that, for simplicity in our present considerations, we suppose each tetrahedron to be wholly scalene, that is to say, the seven lengths found amongst the edges to be all unequal. Next shift the tetrahedrons to bring the edges QE into coincidence, and next again to bring the edges QF into coincidence. Thus, including the primitive parallelepiped, we can make four different parallele-pipeds in each of which six of the tetrahedrons have a common edge.

§ 11. Now take the two pairs of tetrahedrons having edges of length equal to QA, and put them together with these edges coinci-dent. Thus we have a scalene octahedron. The remaining pair of

---

* A pair of gloves are dichirally similar, or enantiomorphs. Equal and similar right-handed gloves are chirally similar.

tetrahedrons placed on a pair of its parallel faces complete a parallelepiped. Similarly two other parallelepipeds may be made by putting together the pairs that have edges of lengths equal to QB and QC respectively with those edges coincident, and finishing in each case with the remaining pair of tetrahedrons. The three parallelepipeds thus found are essentially different from one another, and from the four of § 10; and thus we have the seven parallelepipeds fulfilling the statement of § 9. Each of the seven parallelepipeds corresponds to one and the same homogeneous distribution of points.

§ 12. Going back to § 4, we see that, by the rule there given, we find four different ways of passing to the tetrakaidekahedron from any one chosen parallelepiped of a homogeneous assemblage. The four different cellular systems thus found involve four different sets of seven pairs of neighbours for each point. In each of these there are four pairs of neighbours in rows parallel to the three quartets of edges of the parallelepiped and to the chosen body-diagonal; and the other three pairs of neighbours are in three rows parallel to the face-diagonals which meet in the chosen body-diagonal. The second (§ 11) of the two modes of putting together tetrahedrons to form a parallelepiped which we have been considering suggests a second mode of dividing our primitive parallelepiped, in which we should first truncate two opposite corners and then divide the octahedron which is left, by two planes through one or other of its three diagonals. The six tetrahedrons obtained by any one of the twelve ways of effecting this second mode of division give, by their twenty-four corners, the twenty-four corners of a space-filling tetrakaidekahedronal cell, by which our fundamental problem is solved. But every solution thus obtainable is clearly obtainable by the simpler rule of § 4, commencing with some one of the infinite number of primitive parallelepipeds which we may take as representative of any homogeneous distribution of points.

§ 13. The communication is illustrated by a model showing the six tetrahedrons derived by the rule 4 from a symmetrical kind of primitive parallelepiped, being a rhombohedron of which the axial-diagonal is equal in length to each of the edges. The homogeneous distribution of points corresponding to this form of parallelepiped is the well-known one in which every point is surrounded by eight others at the corners of a cube of which it is the centre; or, if we like to look at it so, two simple cubical distributions of single points, each point of one distribution being at the centre of a cube of points of the other. [To understand the tactics of the single homogeneous assemblage constituted by these two cubic assemblages, let P be a point of one of the cubic assemblages, and Q any one of its four nearest neighbours of the other assemblage. Q is at the centre of a cube of which P is at one corner. Let PD, PE, PF be three conterminous edges of this cube so

that A, B, C are points of the first assemblage nearest to P. Again Q is a corner of a cube of which P is the centre; and if QA, QB, QC are three conterminous edges of this cube, D, E, F are points of the second assemblage nearest to Q. The rhombohedron of which PQ is body-diagonal and PA, PB, PC the edges conterminous in P, and QD, QE, QF the edges conterminous in Q, is our present rhombohedron. The diagram of § 9 (fig. 7), imagined to be altered to proper proportions for the present case, may be looked to for illustration. Its three face-diagonals through P, being PD, PE, PF, are perpendicular to one another. So also are QA, QB, QC, its three face-diagonals through Q. The body-diagonal of the cube PQ, being half the body-diagonal of the cube whose edges are PD, PE, PF, is equal to PD × √⅓: and PA, PB, PC are also each of them equal to this, because A, B, C are centres of other equal cubes, having P for a common corner.—January 30.]

§ 14. The tetrahedrons used in the model are those into which the parallelepiped is cut by three planes through the axial diagonal, which in this case cut one another at angles of 60°. We wish to be able to shift the tetrahedrons into positions corresponding to those of the triangles in fig. 1, which we could not do if they were cut out of the solid. I, therefore, make a mere skeleton of each tetrahedon, consisting of a piece of wire bent at two points, one-third of its length from its ends, at angles of 70⅓°, being $\sin^{-1} \frac{1}{3}\sqrt{3}$, in planes inclined at 60° to one another. The six skeletons thus made are equal and similar, three homochirals and the other three also homochirals, their enantiomorphs. In their places in the primitive parallelepiped they have their middle lines coincident in its axial diagonal PQ, and their other 6 × 2 arms coincident in three pairs in its six edges through P and Q. Looking at fig. 7 we see, for example, three of the edges CP, PQ, QE, of one of the tetrahedrons thus constituted; and DQ, QP, PB, three edges of its enantiomorph. In the model they are put together with their middle lines at equal distances around the axial diagonal and their arms symmetrically arranged round it. Wherever two lines cross they are tied, not very tightly, together by thin cord many times round, and thus we can slip them along so as to bring the six middle lines either very close together, nearly as they would be in the primitive parallelepiped, or farther and farther out from one another so as to give, by the four corners of the tetrahedrons, the twenty-four corners of all possible configurations of the plane-faced space-filling tetrakaidekahedron.

§ 15. The six skeletons being symmetrically arranged around an axial line we see that each arm is cut by lines of other skeletons in three points. For an important configuration, let the skeletons be separated out from the axial line just so far that each arm is divided into four equal parts, by those three intersectional points. The

FIG. 8.

ERRATUM.

'Proceedings,' No. 331, p. 12, line 12.

For $\sqrt{\tfrac{3}{2}}$ *read* $\tfrac{1}{2}\sqrt{3}$.

tetrakaidekahedron of which the twenty-four corners are the corners of the tetrahedrons thus placed may conveniently be called the orthic tetrakaidekahedron. It has six equal square faces and eight equal equiangular and equilateral hexagonal faces. It was described in § 12 of my paper on "The Division of Space with Minimum Partitional Area,"[*] under the name of "plane-faced isotropic tetrakaidekahedron"; but I now prefer to call it orthic, because, for each of its seven pairs of parallel faces, lines forming corresponding points in the two faces are perpendicular to the faces, and the planes of its three pairs of square faces are perpendicular to one another. Fig. 8 represents an orthogonal projection on a plane parallel to one of the four pairs of hexagonal faces. The heavy lines are edges of the tetrakaidekahedron. The light lines are edges of the tetrahedrons of § 13, or parts of those edges not coincident in projection with the edges of the tetrakaidekahedron. The figures 1, 1, 1; 2, 2, 2; . . .; 6, 6, 6 show corners belonging respectively to the six tetrahedrons,

[*] 'Phil. Mag.,' 1887, 2nd half-year, and 'Acta Mathematica,' vol. 11, pp. 121—134.

Fig. 9.

two of the four corners of each being projected on one point in the diagram. Fig. 9 shows, on the same scale of magnitude with corresponding distinction between heavy and light lines, the orthogonal projection on a plane parallel to a pair of square faces.

§ 16. If the rule of § 15 with reference to the division of each arm of a skeleton tetrahedron into four equal parts by points in which it is cut by other lines of skeletons is fulfilled with all details of §§ 14 and 15 applied to any oblique parallelepiped, we find a tetrakaideka-hedron which we may call orthoid, because it is an orthic tetrakai-dekahedron, altered by homogeneous strain. Professor Crum Brown has kindly made for me the beautiful model of an orthoidal tetra-kaidekahedron thus defined which is placed before the Royal Society as an illustration of the present communication.

Fig. 10 is a stereoscopic picture of an orthic tetrakaidekahedron, made by soldering together thirty-six pieces of wire, each 4 in. long, with three ends of wire at each of twenty-four corners.

§ 17. I cannot in the present communication enter upon the most general possible plane-faced partitional tetrakaidekahedron or show its relation to orthic and orthoidal tetrakaidekahedrons. I may

Fig. 10.

merely say that the analogy in the homogeneous division of a plane
is this:—an equilateral and equiangular hexagon (orthic); any other
hexagon of three pairs of equal and parallel sides whose paracentric

diagonals trisect one another (orthoidal). The angles of an orthoidal hexagon, other than equilateral, are not 120°. The angles of the left-hand hexagon fig. 1 (§ 7) are 120°, and its paracentric diagonals do not trisect one another, as the diagram clearly shows.

II. "An Estimate of the Degree of Legitimate Natality, as shown in the Table of Natality compiled by the Author from Observations made at Budapest." By JOSEPH KÖRÖSI, Member of the Hungarian Academy of Sciences, Director of Municipal Statistics. Communicated by Sir JAMES PAGET, F.R.S. Received December 28, 1893.

(Abstract.)

Both branches of the science of demography—natality statistics as well as mortality statistics—originated on British soil. It was in 1665 that the Royal Society published the first work on these matters (Graunt's "Observations"), whilst in 1693 Halley, by establishing the first life table, laid the foundation of the scientific treatment of mortality statistics. These tables of mortality showed for the first time how to measure the probability of *death* for each year of human age. The other branch of vital statistics is still in want of a corresponding table of natality, showing the probability of *birth* for each of the age-combinations of the parents. The table of natality is not of so great scientific importance as the life table, as the probability of death depends on natural laws, whilst the fertility, at least partially, is influenced by voluntary causes also. But as the problems of over-population or de-population are an effect of both forces, it is worth while to study the law of these facts also.

To reach this aim, I have tabulated the age of the 71,800 married couples given in the Census of 1891, conforming to the single year-combinations. The virtual number of these combinations—as 45 productive years of the male have to be combined with each of the 40 productive years of the female—is about 2000. Knowing thus the number of all age-combinations, I observed for four years (two before and two after the Census) the 46,931 births amongst couples of those ages; I got thus, dividing the figures obtained by four, the yearly probability of birth for each age-combination.

As the legitimate natality is to be regarded as a resultant between two distinct forces, the instinct of nature which urges towards multiplication and the forethought which causes moral restraint, it was also desirable to get an insight into the march of the physiological fertility alone. For this purpose I had to look out for couples in whom the moral restraint is weakest or entirely absent. These con-

ditions are fulfilled in newly-married couples, where the physiological factor is nearly exclusively active. I also thus found the degree of physiological natality for different age-combinations. The two curves are very different. The legitimate natality declines after the first child and its fall shows a regular slope. The physiological arrives later at its maximum, remains for some length of time on this culminating height, and decreases only at a more advanced age.

We get thus two degrees of fertility for each age. The difference between the degree of physiological and that of the actual fertility shows, the few cases of procreative exhaustion excepted, the influence of the moral factor. In the somewhat advanced ages this moral restraint exercises an influence exceeding all expectation. With the mothers of 30 to 35 it reduces the fertility to 78 per cent. (instead of 100 per cent.), with those of 43 to 2 per cent., *i.e.*, 98/100 of the physiological faculty is suppressed. With men the influence is also very great, though weaker than with women.

Out of a large number of data here follow some figures to characterise the results :

	For the mother.		For the father.	
The fertility is	Actual.	Physiological.	Actual.	Physiological.
at 25 to 29 years....	29·2 p.c.	30·9 p.c.	35·8 p.c.	28·0 p.c. (?)
„ 30 „ 34 „	20·6 „	32·9 „	27·1 „	27·0 „
„ 40 „ 44 „	5·9 „	20·4 „	13·8 „	21·1 „

The tables containing the fertility of each sex separately I call *monogenous*, the others *bigenous*. Here follow some samples of the bigenous tables :

For husbands of 39 years of age the probability of becoming fathers is :

with a wife of 20 years........ ˙31 p.c.
„   30 „ ... . 20 „

For husbands of 40 years of age :

with a wife of 35 years........ 27 p.c.
„   40 „ .... 17 „
„   45 „ .... 2½ „

I attach a volume of tables containing all the probabilities found, and an atlas of diagrams to make this heavy mass of figures more accessible.

III. " Results derived from the Natality Table of Körösi by employing the Method of Contours or Isogens." By FRANCIS GALTON, F.R.S. Received January 12, 1894.

There are three variables in the statistics of natality. The age of the father is one, that of the mother is another, and the percental offspring of parents of those ages is the third. These three variables may be coordinated in the same way as that which is daily followed at meteorological offices in dealing with (1) the longitudes of the various stations, (2) their latitudes, and (3) the barometric height at each. After these data have been entered on a chart in their proper places, contours, known by the name of isobars, are drawn to show the lines of equal barometric pressure. In natality tables, the ages of the father and the mother take the place of the longitudes and latitudes in weather charts, and lines of similar birth rates, or as I would call them, " isogens," take the place of isobars.

Table I contains the means of each set of four adjacent entries as shown by the arrangement below, the left-hand diagram showing the four entries, and the right-hand one showing their mean. The

entries themselves were copied to the nearest integer from Körösi's tables. The means are recorded in Table I to the nearest integer only, subject to an allowance of correction not exceeding 0·30 for the sake of slight smoothing; thus 24·25, which would otherwise have been entered as 24, might be treated as if it were 24·25+0·30 = 24·55 and be entered as 25. Similarly 24·75 might be entered either as 25 or as 24. It will be seen by the right-hand diagram that the position of the mean corresponds to the first moment of the years shown at the side and top; therefore the interval to which the annual birth rate corresponds is made up of the half year before and after that epoch.

The means that are enclosed in brackets are those in which one or

Table I.—Annual Percentage of Births according to the Ages of the Father and Mother, derived from Kőrösi's Table of Natality at Budapest.

The tabular values refer to the half-year before and after the beginning of the year entered at the top and side.

Age of the mother.	Age of the father (the even years are omitted).																
	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57
19	(40)	46	(42)														
21	44	44	43	38	34	(36)											
23	43	43	41	35	35	33	30	(38)									
25	32	36	38	38	31	30	29	28	(36)								
27	31	33	36	38	31	28	27	26	19	(21)							
29		34	35	31	33	27	27	24	21	23	(17)						
31		24	29	23	24	26	24	21	20	18	17	16					
33			28	25	23	22	23	22	18	17	16	15	(12)				
35			24	19	21	19	21	20	16	15	13	10	12	(9)			
37				(18)	18	21	17	17	18	16	14	13	12	12	(13)		
39					(17)	(16)	16	15	15	13	14	10	9	9	9	(5)	
41						(11)	(12)	13	10	11	10	10	6	8	5	(3)	(5)
43							(6)	(7)	6	6	5	5	4	4	4	(3)	(5)
45								3	3	(4)	3	2	3	2	(2)	(1)	8

more of the four squares from which they were derived was blank. They are, of course, less trustworthy than the rest; moreover, they may depend on less than 100 families.

The ages of married couples are distributed over only about one-half of the squares of Table I, as there are too few examples of other ages to be statistically available. This partial distribution is well seen in the diagram of isogens, where a dotted outline encloses all the material that can be used with safety. The broken line AB corresponds to the instances in which both parents are of the same age. The chart is practically limited to marriages in which the wife is less than five years older, and less than seventeen years younger, than her husband.

Isogens.

Father's Age.

It will be noticed that the isogens run in nearly straight, diagonal, and equidistant lines across the greater part of the chart. If we omit six squares in the upper left-hand corner where there is no room for an isogen, we shall find these diagonal lines to cross 89 of the total number of 118 entries, or between eight and nine tenths of them. This indicates the existence of a very curious and unexpected law of natality, which is well brought out by Table II, which shows the values measured from the dots marked on the isogens. They have been taken at convenient places to serve as examples, one at the beginning, one at the end of the straight portion of each, and at some other intervening places.

In Table II are given the ages of the father and mother that correspond to each of these dots.

As a consequence of the straightness of the isogens, the *sums of the*

Table II. Values of the Isogens at the Dots.

Percentage of births in the year. A	Examples of the corresponding ages of the		B + C.	Accepted mean of B + C.	A + B + C.
	Mother. B	Father. C			
40	23	27¼	50¼	51	91
	21	30	51		
	19¼	31¼	51		
35	26	29	55	55¼	90¼
	24	31¼	55¼		
	22	33¼	55¼		
	20¼	35	55¼		
30	29¼	30¼	60	60¼	90¼
	27	33¼	60¼		
	25	35¼	60¼		
	22¼	38	60¼		
25	32¼	33	65¼	66¼	91¼
	31	35¼	66¼		
	29	37¼	66¼		
	27	39¼	66¼		
	25¼	41	66¼		
20	35¾	35¾	71¼	72	92
	34	38	72		
	32	40	72		
	30	42¼	72¼		
	28¼	44¼	72¼		
15	39	39	78	79	94
	37¼	41	78¼		
	36	43	79		
	34	45¼	79¼		
	31¾	47¾	79¼		
10	41¼	43	84¼	86	96
	39	46¼	85¼		
	37	49¼	86¼		
	35¼	51¼	87		
5	43¼	47	90¼	93	98
	42	50	92		
	40¼	53	93¼		
	39¼	55¼	95		

ages of the parents to which each point in the straight portion of the same isogen refers are *constant.* The difference between their ages is of no account whatever in eight or nine tenths of the total number of marriages ; it is only when the wife is older than the husband or when she approaches the limit of the child-bearing age, that this curious

law ceases to hold true. The connexion between it and the straightness of the isobar is easily understood from the equation to a straight line of $x+y =$ constant, for if x represent the age of the father, f, and if y represent that of the mother, m, then $f+m =$ constant. That this is a fact is conspicuously evident from the columns headed B+C in Table II. This is the first curious law.

Again, through a coincidence between the increasing age of either parent and the decrease of fertility, it happens that the sum of the three elements of (1) father's age, (2) mother's age, (3) percental birth-rate in a year has a value that is itself approximately constant, as is seen in the column headed A+B+C. Its lowest limit is 90$\frac{1}{2}$ and its highest up to the isogen of 10 per cent. is 96, but it has increased to 98 at the isogen of 5 per cent. If we accept for it a constant value of 93 or 94 we shall never be far wrong in the larger part of the chart.

From this follows the second curious law that if we wish to calculate the percental birth-rate per annum for a married couple within the limits of the chart where the isogens run straight and parallel, we have only to add the ages of the father and mother and subtract the total from 93 or 94, in order to obtain it with considerable pre - cision. The approximate limits within which this law obtains are : (1) the wife is not to be older than her husband; (2) she is not to be less than twenty-three years of age, nor (3) more than forty.

Example.—In any large number of husbands and wives living under like conditions to the inhabitants of Budapest, whose respective ages at their nearest birthdays, to 21st June, 1892, were : that of the father, thirty-five, that of the mother, twenty-seven; then the number of children born to them during the year 1892 would be at the rate of $93-(35+27)$ per cent. $= 31$ per cent.; the isogen makes it about 32 per cent.*

I shall not now enter into the other salient peculiarities of the isogens further than to allude to the curious change in their course which occurs when the wife is older than the husband. When she is from thirty to thirty-eight she certainly seems to be appreciably more fertile with a husband of her own age or somewhat older than she is with one who is younger. I should hesitate to ascribe this to physiological causes without corroborative evidence derived from breeders of stock. It is very possible that indifference on the part of young husbands to ageing wives may have something to do with it.

It is almost needless to say that if it be desired to obtain the observed birth-rates for a mother of any specified age and for fathers of

---

* A rough mechanical arrangement was exhibited by which isogens may be drawn. It consists of three sliding pieces connected by a string. A coloured patch is pasted on the back board to show the limits within which the isogens drawn by it are trustworthy.

various ages, the corresponding line of Table I will give the information, while if the smoothed values are wanted, a similar line in the chart of isogens will give them after being smoothed, not in one dimension only *but in two dimensions.* Similarly, as regards the birth-rates for a father of any specified age and for mothers of various ages, by following the vertical columns instead of the horizontal lines.

In conclusion, I would remark that, though the method of isogens applied to Körösi's tables fully discusses the distribution of mean birth-rates, those tables do not enable us to determine the second postulate of paramount importance, namely, the degree of conformity of individual cases to the means of many cases. We know nothing thus far about the facility of error at the various positions in the chart, whether or no it conforms to the normal law of frequency; still less, what is its modulus, or whether the modulus is constant throughout the chart or varies in accordance with some definite law.

The answer to these questions admits of being obtained by a moderate amount of work on the original observations, selecting at first a few squares for exploratory purposes, such as are (1) distributed evenly about the chart, and (2) contain each of them not less than some 300 observations, and (3) whose means accord with the smoothed isogens that pass over the squares, thereby affording satisfactory centres of reference.

IV. "Appendix to a Communication entitled ' The Mechanical Equivalent of Heat.'"[*] By E. H. GRIFFITHS, M.A. Communicated by R. T. GLAZEBROOK, F.R.S. Received December 7, 1893.

Section I.

In a communication which I had the honour of making to the Royal Society in the spring of this year, the following statement occurs (p. 420):—"We are (with the help of Mr. Callendar) now entering on a careful direct comparison of thermometer E_m with a new form of air thermometer, which, there is every reason to believe, will give very accurate results, but we are unable to assign any definite limit to the time that this investigation may take."

A great number of comparisons have been made during the summer of this year by Mr. Callendar and myself between the mercury thermometer E_m used by me for determining the temperature of the calorimeter, the Tonnelot thermometer, No. 11,048, described in the above paper (pp. 426—433), the platinum thermometer N, by which the mercury thermometer E_m had been previously standardised,

---

[*] 'Phil. Trans.,' vol. 184 (1893), A, pp. 361—504.

and two air thermometers constructed by Hicks under Mr. Callendar's direction.*

The indications of these air thermometers are independent of external pressure, and no difficulty was experienced in obtaining the temperature of the bulb to 1/1000° C. The results were, however, not entirely satisfactory. It was found impossible to maintain the *exterior* portion of the tank (where the comparisons had to be made) at a temperature constant to 1/1000° C, especially at higher temperatures. A reference to pp. 374—378 will show that the regulating apparatus was designed to maintain at a constant temperature the *interior* of the steel chamber there described, and this purpose it fulfilled admirably. Fluctuations, however, amounting to as much as 1/100° at 50° C. occurred in the surrounding water, and an element of uncertainty was thus introduced into our comparisons. I am now so modifying the apparatus as to eliminate these fluctuations in the exterior temperature, and thus render the tank more suitable for such observations.

I believe Mr. Callendar proposes to make a communication to this Society in which the details of this comparison will be given, and he has, with this object in view, taken with him to Canada the records of our experiments. I therefore propose on this occasion to confine myself to results. I may, however, mention that extreme care was taken with the cleaning and drying of the air thermometers; observations were made with the thermometers filled with air, hydrogen, and nitrogen, and all the precautions observed which Mr. Callendar's considerable experience of air thermometers could suggest.

The conclusions, as far as they affect my previous determinations of temperature, are that over the range through which the experiments were conducted (14° to 26° C.) the limit of error does not exceed 0·003° C. of the nitrogen thermometer. An error of such a magnitude would affect my final value of J by about 1 in 4000.

Another possible cause of error, mentioned on p. 424, is the difference caused by unequal lag of the rising mercury thermometer at the beginning and end of the temperature range, and I have pointed out on p. 424 that a possible error of 0·008° C. might be due to this cause.

I have recently performed the experiments by which I hoped to throw some light on this point—using as a thermometer a naked platinum wire immersed in pentane. The experiments are difficult to conduct, and I do not regard the results as entirely satisfactory. They agree with my former experiments in indicating that the lag is greater at the beginning than at the end of the range by a quantity between 0·002° and 0·009° C. The mean result of my observations gives 0·004° C.

* For a description of these air thermometers see 'Roy. Soc. Proc.,' January, 1891.

as the difference, which would diminish our temperature range by about 1 in 3000, and would increase the value of J by a proportionate amount, although it would not affect the temperature coefficients of the capacity for heat of water or the specific heat of the calorimeter. I do not, however, feel that this point is sufficiently established to make it advisable to apply the correction to the previously published results.

Section II.

I regret to state that we have discovered a serious error in the arithmetic.

On pp. 407—410 is given an account of the comparison of the coils in the resistance-box with the B.A. standards, and Table XI gives in full the numbers actually obtained during the comparison. In order to simplify our work we constructed a table for our own use which gave the value of each coil in terms of a legal ohm, and afterwards transferred them (see p. 410) into true ohms. Unfortunately the 10-ohm coil in the bridge arm was entered in this private table as 10·0077, whereas it ought to have been 9·9977—an error of 1 in 1000, having its origin in a mistake in addition. The experimental numbers actually given in Table XI will show that the ratio of the bridge arms was 9·9734/997·87, that is, 0·0099947, or, if expressed in legal ohms, 9·9977/1000·30 instead of 10·0077/1000·30, as given on line 13, p. 410.

The mistake is obvious to anyone who compares the numbers given in Table XI with the conclusion drawn on p. 410. The whole of the arithmetic was carefully revised by both Mr. Clark and myself, but an error of this kind in simple addition is precisely the one to escape observation. The annoying circumstance is that a similar mistake in any of the other coils would have had no appreciable effect on our conclusions, but occurring as it did in the ratio of the bridge arms it affects all succeeding tables.

I would venture to add that this incident shows how advisable it is, in work of this kind, to give in full all the experimental numbers on which the conclusions are based.

In consequence of this discovery I have carefully again revised nearly the whole of the calculations, but I am glad to say that with the exception of two or three obvious misprints I am unable to detect any further arithmetical mistakes.

The effect of the correction thus rendered necessary is to decrease the value of R, in all the tables where the reduction to *true ohms* is given, by 1 in 1000; hence the value of T in Tables XXXVII, XL, XLI must be increased in the same proportion. The resulting correction is a simple one, for, as the value of J varies directly as T, it has only to be increased by 1 in 1000. Fortunately the temperatures

as obtained by the platinum thermometers are independent of the ratio of the bridge arms, and are, therefore, unaffected. The values of the temperature coefficients, of the capacity for heat of water and of the specific heat of the calorimeter, remain practically unaltered, as the correction only affects the sixth significant figure.

The corrected value of J in terms of a thermal unit at 15° C. is thus $(4\cdot1940 + 0\cdot0042) \times 10^7 = 4\cdot1982 \times 10^7$, and I estimate the limit of error due to the causes mentioned in Section I of this Appendix as $\pm 0\cdot0020$.

Hence (assuming that $g = 981\cdot17$),

J = 427·88 kilogramme-metres in latitude of Greenwich.

J = 1403·6 ft.-lbs. per thermal unit C. in latitude of Greenwich.

J = 779·77   „   „   F   „   „

V. " On the Reflection and Refraction of Light."   By G. A. Schott, B.A. (Cantab.), B.Sc. (Lond.), formerly Scholar of Trinity College, Cambridge.   Communicated by R. T. Glazebrook, M.A., F.R.S.   Received November 29, 1893.

(Abstract.)

The object of this paper is to examine the consequences of supposing the transition between different refractive media to be effected continuously through a thin variable layer, to deduce expressions for the amplitudes and changes of phase of the reflected and refracted light, and to compare them with the results of experiments hitherto made on that subject.

The theories examined are the elastic solid theories, both those assuming large velocities for the pressural wave, including Green's, Voigt's, and K. Pearson's theories, and also Lord Kelvin's contractile ether theory, and then the electromagnetic theory, in the form given by Hertz, which, it may be remarked, leads to the same equations as the contractile ether theory.

The medium being continuously variable, the displacements and stresses, or the electric and magnetic force components, are everywhere continuous. The method thus avoids all hypotheses as to boundary conditions at surfaces of discontinuity.

For convenience, the first constant portion of the medium, from which the incidental light comes, is called the first medium, the second constant part, into which the light is in part refracted, is called the second medium, the thin variable part is called the variable layer, and the arbitrarily chosen planes, which include the whole of the variable layer, are called the boundaries of the layer. Since at those planes the medium is continuous, the displacements and stresses have the same values on both sides of each plane.

In the first medium are assumed an incident, a reflected, and a pressural wave, and in the second a refracted and a pressural wave, the pressural waves, of course, disappearing on the contractile ether and electromagnetic theories. Taking account both of vibrations in and perpendicular to the plane of incidence, there are 6 amplitudes and 6 retardations of phase, in all, 12 constants, to be determined. From the continuity of the motion at the two boundary planes of the variable layer are obtained 12 pairs of equations, of which 6 pairs determine the motion inside the variable layer, and the remaining ones the 6 pairs of constants. In the actual work, imaginaries are used in the usual way, reducing the equations by one half, the requisite number of equations being obtained at the end by changing the sign of the imaginary.

From the equations of vibration in the variable layer and one half of the boundary conditions, solutions are obtained in ascending powers of the thickness of the layer, which, on substitution in the remaining boundary conditions, give sufficient equations to determine the amplitudes and phases by simple though long algebraic analysis.

The solutions are found to be convergent, provided $2\pi d/\lambda$ is less than the reciprocal of the greatest value of the refractive index occurring in the variable layer, d being its thickness, and λ the wavelength *in vacuo* of the light employed. This condition gives values for d which are less than the thickness of a soap film producing a red of the first order. Thus the films for which the theory holds at all cannot possibly produce colours of thin plates, which has been stated as a possible objection by Lord Rayleigh.

The solutions are taken as far as is necessary to give the values of the amplitudes and phases correct to squares of d. The elastic solid theories lead to Green's formulæ, but the contractile ether and electromagnetic theories give modifications of Fresnel's formulæ, somewhat of Cauchy's type. The corrections to the amplitudes are of order d^2, whilst the phases are of order d. If μ_0, μ_1, μ are the refractive indices of the media and the layer, then these terms involve certain constants which are functions of μ_0, μ_1 and of the mean values of μ^2, $1/\mu^2$ and certain combinations of μ^2, $1/\mu^2$.

The effect is considered of supposing the velocities of the pressural waves to be large, but finite and different, the refractive index for the pressural wave from the first to the second medium having any value. The resulting formulæ deviate from Green's chiefly in that

$$\mathbf{M} = \frac{\mu_1{}^2 - \mu_0{}^2}{\mu_1{}^2 + \mu_0{}^2} \text{ becomes } \frac{\mu_1{}^2 - \mu_0{}^2}{\mu_1{}^2 + \mu_0{}^2}\left[1 + \frac{\mu_1\mu_0}{2(\mu_1{}^2 + \mu_0{}^2)}\frac{1/m_1{}^2 + 1/m_1{}^2}{\sin i_0 \sin i_1}\right], \text{ where}$$

m_0, m_1 are the large ratios of the pressural to the light velocity in the two media; and this value of M holds for values of i_0, i_1 so large that $\sin i_0 > 1/m_0$ and $\sin i_1 > 1/m_1$. The effect is always to increase M, and thus Haughton's proposal to substitute for Green's M a

quantity $(\mu^2-1)/(\mu^2+1)$, in which μ represents the refractive index of the pressural waves or a quantity of that nature which is to be made nearly equal to unity, cannot on any rigid theory be accepted. Hence neither Green's theory, nor any other rigid elastic solid theory, such as that of Voigt or of K. Pearson, can be made to agree with experiment, if we suppose the ether incompressible. The alternative assumption of supposing the ether contractile, will be found to agree with experiment, but there is no means of deciding between it and the electromagnetic theory as regards refraction and reflection.

These theories lead to the following expressions for the ratio of the intensities and the difference of phase of the components, polarised parallel and perpendicular to the plane of incidence, of the reflected light—

$$\left(\frac{R\perp}{R//}\right)^2 = \frac{\cos^2(i_0+i_1)}{\cos^2(i_0-i_1)} + A\frac{\sin i_0 \sin i_1 \cos i_0 \cos i_1 \cos(i_0+i_1)}{\cos^3(i_0-i_1)}$$

$$+ B\frac{\sin^2 i_0 \sin^2 i_1 \cos i_0 \cos i_1}{\cos^4(i_0-i_1)},$$

$$\tan(\rho\perp-\rho//)$$

$$= \frac{E\sin^2 i_0 \cos i_0}{\cos(i_0-i_1)\cos(i_0+i_1)(1+D^2\cos^2 i_0)+DE\sin^2 i_0 \cos^2 i_0},$$

where $R\perp$, $R//$ are the amplitudes, $\rho\perp$, $\rho//$ the phase retardations of the components polarised perpendicularly ($\perp$) and parallel ($//$) to the plane of incidence, the amplitude of each incident component being taken as unity, i_0, i_1 are the angles of incidence and refraction, and A, B, D, E are four constants depending on the refractive indices of the two media and on the constitution of the variable layer and satisfying the theoretical conditions $B = (\mu_1/\mu_0)E^2$, and the conditions that when the two media are inverted, that is, μ_0, μ_1 interchanged, A, B remain unchanged, and $\mu_1 E$ change sign.

The expressions for $(R\perp/R//)^2$ and for $\tan(\rho\perp-\rho//)$ show that the change of difference of phase depends chiefly on E, being also slightly modified by D, and that the alteration in amplitude depends chiefly on B, being only slightly affected by A. The accuracy with which the constants can be experimentally determined is thus very different, being greatest for E, less for B, and least for D and A.

The values of the four constants are independently calculated for several pairs of media from experiments by Jamin, by Kurz, and by Quincke, using the method of least squares and assuming that the observations are equally exact at all incidences, which is only roughly true.

The numbers for the ratio intensities and the difference of phase calculated with the values of the constants agree rather better with

observation than the corresponding numbers for Cauchy's formulæ, even as modified by Quincke to explain his experiments. For instance, in the case of Jamin's experiments on realgar-air, chosen at random, the probable errors of a single observation are—according to theory, in $\tan^{-1}(R_\perp/R_{//})$, $20'\cdot82$, according to Cauchy, $22'\cdot96$, and in the difference of phase $\rho_\perp - \rho_{//}$, measured in wave-lengths, according to the theory, $0\cdot0054$, according to Cauchy, $0\cdot0071$. This superiority is due to the influence of the additional constants D and A; but their effect is very slight, that of A especially so; in some cases A may be put zero without greatly impairing the accuracy of the theoretical formulæ.

The values of B, as determined from the intensity experiments agree within the limits of error with those deduced from the equation $B = (\mu_1/\mu_0)E^2$; in the one case of essence of lavender-air there is a serious discrepancy, for B is $0\cdot000027$, while $(\mu_1/\mu_0)E^2$ is $0\cdot000065$; but here the error is due to the smallness of B, ten times less than for any other pair of media; in fact the minimum value of $(R_\perp/R_{//})^2$ is only $\tan^2 7'$ or $0\cdot000004$, and an error of only a few minutes in the determination of the azimuth would make a great difference in the value of B. In cases of such difference between B and $(\mu_1/\mu_0)E^2$, it is best to rely on the value of E, which can be determined with much greater accuracy than B, in some cases with more than five times greater accuracy.

As regards the interchange of media, there were available three sufficiently accurate sets of experiments by Quincke. The conditions referred to above are satisfied with very good accuracy in the case of flintglass-air, the values of B being $0\cdot00533$ and $0\cdot0050$, and of μ_1E, $-(\mu_1E)'$, $0\cdot0925$, $0\cdot093$; for flintglass-water the numbers are, B, $0\cdot0120$, $0\cdot0100$, and μ_1E, $0\cdot1490$, $-(\mu_1E)'$, $0\cdot1426$; but for crownglass-air the discrepancy is great, B, $0\cdot00040$, $0\cdot00111$, and μ_1E, $0\cdot0237$, $-(\mu_1E)'$, $0\cdot0427$.

Jamin and Cauchy's corresponding relation between the ellipticities, $-E'/E = \mu_1/\mu_1'$, is not so nearly satisfied; the observed values of $-E'/E$ are in the three cases, $1\cdot741$, $1\cdot244$, and $3\cdot446$, instead of $1\cdot616$, $1\cdot210$, and $1\cdot515$. More accurate experiments will be necessary to test this point.

Cauchy's theory leads to a relation between the ellipticities of three media taken two and two, $\dfrac{E_{12}}{\mu_1} + \dfrac{E_{23}}{\mu_2} + \dfrac{E_{31}}{\mu_3} = 0$, which relation has been tested by Quincke and found not at all in accordance with experiment.

The above theory has the advantage in requiring no such relation.

The theory discussed above merely requires the existence of a transition film, whether due to actual transition between the ether of the two media or to an adventitious accumulation of dust,

moisture, or condensed gases, or to combinations of these causes. And it affords an explanation of the details of reflection, which is rigid, and at least as good as the representation given by the empirical formulæ of Cauchy, even as modified by Quincke.

VI. "On the Transformation of Optical Wave-Surfaces by Homogeneous Strain." By OLIVER HEAVISIDE, F.R.S. Received December 20, 1893.

Simplex Eolotropy.

1. All explanations of double refraction (proximate, not ultimate) rest upon the hypothesis that the medium in which it occurs is so structured as to impart eolotropy to one of the two properties, associated with potential and kinetic energy, with which the ether is endowed in order to account for the transmission of waves through it in the simplest manner. It may be elastic eolotropy, or it may be something equivalent to eolotropy as regards the density. In Maxwell's electromagnetic theory the two properties are those connecting the electric force with the displacement, and the magnetic force with the induction, say the permittivity and the inductivity, or c and μ. These are, in the simplest case, constants corresponding to isotropy. The existence of eolotropy as regards either of them will cause double refraction. Then either c or μ is a symmetrical linear operator, or dyadic, as Willard Gibbs calls it. In either case the optical wave-surface is of the Fresnel type. In either case the fluxes displacement and induction are perpendicular to one another and in a wave-front, whilst the electric and magnetic forces are also perpendicular to one another. But it is the magnetic force that is in the wave-front, coincident with the induction, in case of magnetic isotropy and electric eolotropy, the electric force being then out of the wave-front, though in the plane of the normal and the displacement. And in the other extreme case of electric isotropy and magnetic eolotropy, the electric force is in the wave-front, coincident with the displacement, whilst the magnetic force is out of the wave-front, though in the plane of the normal and the induction. Now, as a matter of fact, crystals may be strongly eolotropic electrically, whilst their magnetic eolotropy, if existent, is insignificant. This, of course, justifies Maxwell's ascription of double refraction to electric eolotropy.

Properties connected with Duplex Eolotropy.

2. When duplex eolotropy, electric and magnetic, is admitted, we obtain a more general kind of wave-surface, including the former two

as extreme cases. It is almost a pity that magnetic eolotropy should
be insensible, because the investigation of the conditions regulating
plane waves in media possessing duplex eolotropy, and the wave-
surface associated therewith, possesses many points of interest. The
chief attraction lies in the perfectly symmetrical manner in which the
subject may be displayed, as regards the two eolotropies. This brings
out clearly properties which are not always easily visible in the case
of simplex eolotropy, when there is a one-sided and imperfect
development of the analysis concerned.

In general, the fluxes displacement and induction, although in the
wave-front, are not coperpendicular. Corresponding to this, the two
forces electric and magnetic, which are always in the plane perpen-
dicular to the ray, or the flux of energy, are not coperpendicular.
Nor are the positions of the fluxes in the wave-front conditioned by
the effective components in that plane of the forces being made to
coincide with the fluxes. There are two waves with a given normal,
and it would be impossible to satisfy this requirement for both. But
there is a sort of balance of skewness, inasmuch as the positions of
the fluxes in the wave-front are such that the angle through which
the plane containing the normal and the displacement (in either
wave) must be turned, round the normal as axis, to reach the electric
force, is equal (though in the opposite sense) to the angle through
which the plane containing the normal and the induction must be
turned to reach the magnetic force. These are merely rudimentary
properties. I have investigated the wave-surface and associated
matters in my paper " On the Electromagnetic Wave-surface "
(' Phil. Mag.,' June, 1885 ; or ' Electrical Papers,' vol. 2, p. 1).

Effects of straining a Duplex Wave-surface.

3. The connexion between the simplex and duplex types of wave-
surface has been interestingly illustrated lately by Dr. J. Larmor in
his paper " On the Singularities of the Optical Wave-surface,"
(' Proc. London Math. Soc.,' vol. 24, 1893). He points out, inci-
dentally, that a simplex wave-surface, when subjected to a particular
sort of homogeneous strain, becomes a duplex wave-surface of a special
kind. To more precisely state the connexion, let there be electric
eolotropy, say c, with magnetic isotropy. Then, if the strainer, or
strain operator, applied to the simplex wave-surface, be homologous
with c, given by $c^{-\frac{1}{2}} \times$ constant, the result is to turn it into a duplex
wave-surface whose two eolotropies are also homologous with the
original c; that is to say, the principal axes are parallel. This duplex
wave-surface is, of course, of a specially simplified kind, though not
the simplest. That occurs when the two eolotropies are not merely
homologous, but are in constant ratio. The wave-surface then re-
duces to a single ellipsoid.

Conversely, therefore, if we start with the duplex wave-surface corresponding to homologous permittivity and inductivity, and homogeneously strain it, the strainer being proportional to c^{i}, we convert it to a simplex wave-surface whose one eolotropy is homologous with the former two.

Remembering that the equation of the duplex wave-surface is symmetrical with respect to the two eolotropies, so that they may be interchanged without altering the surface, it struck me on reading Dr. Larmor's remarks that a similar reduction to a simplex wave-surface could be effected by a strainer proportional to μ^{i}. This was verified on examination, and some more general transformations presented themselves. The results are briefly these :—

Any duplex wave-surface (irrespective of homology of eolotropies), when subjected to homogeneous strain (not necessarily pure), usually remains a duplex wave-surface. That is, the transformed surface is of the same type, though with different inductivity and permittivity operators.

But in special cases it becomes a simplex wave-surface. In one way the strainer is $c^{i}/[c^{i}]$, where the square brackets indicate the determinant of the enclosed operator. In another the strainer is $\mu^{i}/[\mu^{i}]$. These indicate the strain operator to be applied to the vector of the old surface to produce that of the new one.

Now, these simplex wave-surfaces may be strained anew to their reciprocals with respect to the unit sphere, or the corresponding index-surfaces, which are surfaces of the same type. So we have at least four ways of straining any duplex wave-surface to a simplex one.

Furthermore, any duplex wave-surface may be homogeneously strained to its reciprocal, the corresponding index-surface, of the same duplex type. The strain is pure, but is complicated, as it involves both c and μ. The strainer is $c^{-1}(c\mu^{-1})^{i}$, divided by the determinant of the same. This transformation is practically the generalization for the duplex wave-surface of Plücker's theorem relating to the Fresnel surface, for that also involves straining the wave-surface to its reciprocal.

Instead of the single strain above mentioned, we may employ three successive pure strains. Thus, first strain the duplex wave-surface to a simplex surface. Secondly, strain the latter to its reciprocal. Thirdly, strain the last to the reciprocal of the original duplex wave-surface. There are at least two sets of three successive strains which effect the desired transformation. The investigation follows.

Forms of the Index- and Wave-surface Equations, and the Properties of Inversion and Interchangeability of Operators.

4. Let the electric and magnetic forces be **E** and **H**, and the

corresponding fluxes, the displacement and induction, be **D** and **B**, then

$$D = c\mathbf{E}, \qquad\qquad B = \mu\mathbf{H}, \tag{1}$$

where c is the permittivity and μ the inductivity, to be symmetrical linear operators in general. We have also the circuital laws

$$\text{curl } \mathbf{H} = c\dot{\mathbf{E}}, \qquad\qquad -\text{curl } \mathbf{E} = \mu\dot{\mathbf{H}}. \tag{2}$$

Now, if we assume the existence of a plane wave, whose unit normal is **N**, propagated at speed v without change of type, and apply these equations, we find that **D** and **B** are in the wave-front, **E** and **H** are out of it, and that there are two waves possible. We are led directly to the velocity equation, a quadratic in v^2, giving the two values of v^2 belonging to a given **N**. Next, if we put $\mathbf{s} = \mathbf{N}/v$, then $\mathbf{s}$ is the vector of the index-surface, and its equation is

$$\mathbf{s}\frac{\mathbf{s}}{c^{-1}-\dfrac{\mu^{-1}}{[\mu^{-1}](\mathbf{s}\mu\mathbf{s})}} = 0 = \mathbf{s}\frac{\mathbf{s}}{\mu^{-1}-\dfrac{c^{-1}}{[c^{-1}](\mathbf{s}c\mathbf{s})}}, \tag{3}$$

which are, of course, equivalent to the velocity equation ('El. Pa.,' vol. 2, p. 11, equations (41)). Two forms are given, for a reason that will appear later. I employ the vector algebra and notation of the paper referred to, and others. Sufficient to say here that c^{-1} and μ^{-1} are the reciprocals of c and μ; and that $\mathbf{s}c\mathbf{s}$ means the scalar product of $\mathbf{s}$ and $c\mathbf{s}$; for example, if referred to the principal axes of c,

$$\mathbf{s}c\mathbf{s} = c_1 s_1^2 + c_2 s_2^2 + c_3 s_3^2, \tag{4}$$

if c_1, c_2, c_3 be the principal c's (positive scalars, to ensure positivity of the energy), and s_1, s_2, s_3 be the components of $\mathbf{s}$. Also, $[c^{-1}]$ denotes the determinant[*] of c^{-1}, that is, $(c_1 c_2 c_3)^{-1}$.

The operators in the denominators of (3) may be treated, for our purpose, as linear operators themselves. But it is their reciprocals that occur. For example, the first form of (3) may be written

$$\mathbf{s}\left[c^{-1}-\frac{\mu^{-1}}{[\mu^{-1}](\mathbf{s}\mu\mathbf{s})}\right]^{-1}\mathbf{s} = 0, \tag{5}$$

asserting that the vectors $\mathbf{s}$ and $[\ldots]^{-1}\mathbf{s}$ are perpendicular. The expansion of (3) to Cartesian form may be done immediately if c and μ are homologous, for then we may take the reference axes $\mathbf{i}, \mathbf{j}, \mathbf{k}$ parallel to those of c and μ, and at once produce

[*] It occurs to me in reading the proof that the use of $[c]$ to denote the determinant of c, which is plainer to read in combination with other symbols than $|c|$, is in conflict with the ordinary use of square brackets, as in (5) and some equations near the end. But there will be no confusion on this account in the present paper.

$$\frac{s_1{}^2}{\dfrac{1}{c_1} - \dfrac{\mu_2\mu_3}{s\mu s}} + \frac{s_2{}^2}{\dfrac{1}{c_2} - \dfrac{\mu_3\mu_1}{s\mu s}} + \frac{s_3{}^2}{\dfrac{1}{c_3} - \dfrac{\mu_1\mu_2}{s\mu s}} = 0, \qquad (6)$$

where $s\mu s$ is as in (4), with μ written for c. Similarly as regards the second form of (3). When the operators are not homologous, the complication of the form of the constituents of the inverse operators makes the expansion less easy.

As regards the second form of (3), it is obtained from the first form by interchanging μ and c. It represents the same surface. The transformation from one form to the other, if done by ordinary algebra, without the use of vectors and linear operators, is very troublesome in the general case. But in the electromagnetic theory the equivalence can be seen to be true and predicted beforehand. For consider the circuital equations (2). If we eliminate **H**, we obtain

$$-\operatorname{curl} \mu^{-1} \operatorname{curl} \mathbf{E} = c\dot{\mathbf{E}}, \qquad (7)$$

whilst if we eliminate **E**, we obtain

$$-\operatorname{curl} c^{-1} \operatorname{curl} \mathbf{H} = \mu\ddot{\mathbf{H}}. \qquad (8)$$

These are the characteristic equations of **E** and **H** respectively in a dielectric with duplex eolotropy, and we see that they only differ in the interchange of c and μ. When, therefore, we apply one of them, say that of **E**, to a plane wave to make the velocity equation, in which process **E** is eliminated, we can see that a precisely similar investigation applies to the **H** equation, provided μ and c be interchanged. So, if the **E** equation leads to the first form in (3), the **H** equation must lead to the second form. They therefore represent the same surface. The same property applies to any equation obtained from the circuital equations with the electrical variables eliminated, the equation of the wave-surface, for example. If we have obtained one special form, a second is got by interchanging the eolotropies.

The index equation being what we are naturally led to from the characteristic equation, it is merely a matter of mathematical work to derive the corresponding wave-surface. For **s** is the reciprocal of the perpendicular upon the tangent plane to the wave-surface, so that

$$\mathbf{rs} = 1, \qquad (9)$$

if **r** is the vector of the wave-surface; and from the equation of **s** and its connexion with **r**, we may derive the equation of **r** itself. I have shown (*loc. cit.*, vol. 2, pp. 12—16) that the result is expressed by simply inverting the operators in the index equation. Thus, the equation of the wave-surface is

$$\cfrac{\mathbf{r}}{c - \cfrac{\mu}{[\mu]\,(\mathbf{r}\mu^{-1}\mathbf{r})}} = 0 = \mathbf{r}\,\cfrac{\mathbf{r}}{\mu - \cfrac{c}{[c]\,(\mathbf{r}c^{-1}\mathbf{r})}}, \qquad (10)$$

where, as before, two forms are given. Now, the final equivalence of this transition from the index to wave-equation to mere inversion of the two eolotropic operators is such a simple result that one would think there should be a very simple way of exhibiting how the transition comes about. Nevertheless, I am not aware of any simple investigation, and, in fact, found the transition rather difficult, and by no means obvious at first. I effected the transformation by taking advantage of symmetrical relations between the forces and fluxes; in particular proving, first, that $\mathbf{rE} = 0 = \mathbf{rH}$, or that the ray is perpendicular to the electric and magnetic forces, comparing this with the analogous property $\mathbf{sD} = 0 = \mathbf{sB}$, and constructing a process for leading from the former to the wave-equation analogous to that leading from the latter to the index equation. It then goes easily. However, we are not concerned with these details here.

A caution is necessary regarding the interchangeability of μ and c. They should be fully operative as linear operators. If one of them be a constant initially, and therefore all through, we may not then interchange them in the simplified equations which result. For example, let μ be constant in (10). We have now

$$\mathbf{r}\,\cfrac{\mathbf{r}}{c - \cfrac{1}{\mu \mathbf{r}^2}} = 0 = \mathbf{r}\,\cfrac{\mathbf{r}}{\mu - \cfrac{c}{[c]\,(\mathbf{r}c^{-1}\mathbf{r})}}. \qquad (11)$$

The first form is what we are naturally led to by initial assumption of constancy of μ. Now observe that the interchange of μ and c in the secoud form gives us the first form, after a little reduction, remembering that $[\mu]$ is now μ^3. But the same interchange in the first form does not produce the second, because it is more general. So we have gained a relative simplicity of form at the cost of generality. The extra complication of the duplex wave-surface is accompanied by general analytical extensions which make the working operations more powerful. The equivalence of the two forms in (11) may be established by the use of Hamilton's general cubic equation of a linear operator, as done in Tait's work. Though not difficult to carry out, the operations are rather recondite. On the other hand, the much more general equivalence (10) is, as we saw for the reason following (7) and (8), obviously true. This suggests that some other transformations involving the general cubic may be made plainer by generalizing it, employing a pair of linear operators.

General Transformation of Wave-surface by Homogeneous Strain.

5. Now apply a homogeneous strain to the wave-surface. Let

$$q = \frac{\phi}{[\phi]} r.\tag{12}$$

We need not suppose that the strain is pure. Use (12) in the first of (10). It becomes

$$\phi^{-1}q \frac{\phi^{-1}q}{c - \frac{\mu}{[\mu][\phi]^2(\phi^{-1}q\mu^{-1}\phi^{-1}q)}} = 0.\tag{13}$$

Now the use of vectors and linear operators produces such a concise exhibition of the essentially significant properties, freed from the artificial elaboration of coordinates, that a practised worker may readily see his way to the following results by mere inspection of equation (13), or with little more. I give, however, much of the detailed work that would then be done silently, believing that the spread of vector analysis is not encouraged by the quaternionist's practice of leaving out too many of the steps.

In the first place, $\phi^{-1}q$ is the same as $q\phi'^{-1}$, if ϕ' is the conjugate of ϕ. So

$$\phi^{-1}q\mu^{-1}\phi^{-1}q = q\phi'^{-1}\mu^{-1}\phi^{-1}q\tag{14}$$

in the denominator. Also, the first $\phi^{-1}q$ in (13) may be written $q\phi'^{-1}$, and the postfactor ϕ'^{-1} may then be transferred to the denominator. To do this, it must be inverted, of course, and then brought in as a postfactor. Similarly, the ϕ^{-1} in the numerator may be merged in the denominator by inversion first, and then bringing it in as a prefactor. We may see why this is to be done by the elementary formula

$$a^{-1}b^{-1}c^{-1} = (cba)^{-1},\tag{15}$$

where a, b, c are any linear operators. So (13) becomes

$$q \frac{q}{\phi c\phi' - \frac{\phi\mu\phi'}{[\mu][\phi]^2(q\phi'^{-1}\mu^{-1}\phi^{-1}q)}} = 0.\tag{16}$$

Now introduce some simplifications of form. Let

$$\phi c\phi' = b, \qquad\qquad \phi\mu\phi' = \lambda.\tag{17}$$

It follows from the second, and by (15), that

$$\phi'^{-1}\mu^{-1}\phi^{-1} = (\phi\mu\phi')^{-1} = \lambda^{-1}.\tag{18}$$

We also have $$[\lambda] = [\mu][\phi]^2.\tag{19}$$

These three, (17) to (19), reduce (16) to

$$q\cfrac{q}{b-\cfrac{\lambda}{[\lambda]\,(q\lambda^{-1}q)}}=0=q\cfrac{q}{\lambda-\cfrac{b}{[b]\,(qb^{-1}q)}},\qquad (20)$$

where the second form is got from the first by interchanging λ and b, which is permissible on account of the interchangeability of μ and c.

Comparing (20) with (10), we see that there is identity of form. Consequently (20) represents a duplex wave-surface whose operators are b and λ, provided they are self-conjugate. They are, for, by the elementary formula

$$(abc)' = c'b'a',\qquad (21)$$

it follows that $\qquad\qquad \phi c\phi' = (\phi c\phi')',\qquad (22)$

and similarly for the other one.

In case the strain is a pure rotation, we may take the form of ϕ (following Gibbs) as

$$\phi = \quad \mathbf{i} + \mathbf{J}.\mathbf{j} + \mathbf{K}.\mathbf{k},\qquad (23)$$

where $\mathbf{i}, \mathbf{j}, \mathbf{k}$ is one, and $\mathbf{I}, \mathbf{J}, \mathbf{K}$ another set of coperpendicular unit vectors. For, obviously, this makes

$$\phi\mathbf{r} = \mathbf{I}.\mathbf{i}\mathbf{r} + \mathbf{J}.\mathbf{j}\mathbf{r} + \mathbf{K}.\mathbf{k}\mathbf{r} = \mathbf{I}x + \mathbf{J}y + \mathbf{K}z.\qquad (24)$$

Special Cases of Reduction to a Simplex Wave-surface.

6. Now take some special forms of ϕ. We see, by inspection of (17), that we can reduce either of b or λ to a constant. Thus, first,

$$\phi = \mu^{-\frac12}, \qquad \lambda = 1, \qquad b = \mu^{-\frac12}c\mu^{-\frac12}.\qquad (25)$$

Then (20) reduces to

$$q\cfrac{q}{b-\cfrac{1}{q^2}}=0=q\cfrac{q}{1-\cfrac{b}{[b]\,(qb^{-1}q)}},\qquad (26)$$

showing that the original duplex wave-surface is reduced to a simplex one involving eolotropy b, given by (25).

Similarly, a second way is

$$\phi = c^{-\frac12}, \qquad b = 1, \qquad \lambda = c^{-\frac12}\mu c^{-\frac12},\qquad (27)$$

which reduces (20) to the simplex wave-surface

$$q\cfrac{q}{1-\cfrac{\lambda}{[\lambda]\,(q\lambda^{-1}q)}}=0=q\cfrac{q}{\lambda-\cfrac{1}{q^2}},\qquad (28)$$

involving the eolotropy λ.

The new surfaces (26), (28) may now be strained to their reciprocals.   Thus, take the first of (26), and put

$$\mathbf{p} = \frac{b^{-\frac{1}{2}}}{[b^{-\frac{1}{2}}]} \mathbf{q}.$$

(29)

This makes

$$b^{\frac{1}{2}}\mathbf{p} \frac{b^{\frac{1}{2}}\mathbf{p}}{b - \frac{[b^{\frac{1}{2}}]^{2}}{(b^{\frac{1}{2}}\mathbf{p})^{2}}} = 0.$$

(30)

Here the initial and final $b^{\frac{1}{2}}$'s may be removed to the denominator, and, since we also have

$$(b^{\frac{1}{2}}\mathbf{p})^{2} = b^{\frac{1}{2}}\mathbf{p}b^{\frac{1}{2}}\mathbf{p} = \mathbf{p}b\mathbf{p},$$

(31)

we bring the first of (26) to

$$\mathbf{p}\frac{\mathbf{p}}{1 - \frac{b^{-1}}{[b^{-1}](\mathbf{p}b\mathbf{p})}} = 0.$$

(32)

Now compare this with the second form of the same (26).   They are identical, except that b is now inverted.   Consequently (32) represents the index-surface corresponding to the wave-surface represented by the second of (26), and therefore by the first, since they are the same.   In a similar manner the strain (29) applied to the second of (26) leads to the reciprocal of the first form.

In like manner the simplex surface (28) is strained to its reciprocal by

$$\mathbf{p} = \frac{\lambda^{-\frac{1}{2}}}{[\lambda^{-\frac{1}{2}}]} \mathbf{q}.$$

(33)

Applied to the first form of (28), we get the second form with λ inverted; and, applied to the second form, we get the first, with λ inverted.   These inversions of simplex wave-surfaces by homogeneous strain are equivalent to Plücker's theorem showing that the Fresnel wave-surface is its own reciprocal with respect to a certain ellipsoid (Tait, ' Quaternions,' 3rd Ed., p. 342).

Transformation from Duplex Wave- to Index-surface by a Pure Strain.

7. What is of greater interest here is the generalization of this property for the duplex wave-surface itself.   Take

$$\phi = c^{-1}(c\mu^{-1})^{\frac{1}{2}}.$$

(34)

Then we obtain

$$\phi c\phi = c^{-1}(c\mu^{-1})^{\frac{1}{2}}cc^{-1}(c\mu^{-1})^{\frac{1}{2}} = \mu^{-1},$$

(35)

$$\phi\mu\phi = c^{-1}(c\mu^{-1})^{\frac{1}{2}}\mu c^{-1}(c\mu^{-1})^{\frac{1}{2}} = c^{-1}, \tag{36}$$

the first of which is obvious, whilst in the second we make use of

$$\mu c^{-1} = (c\mu^{-1})^{-1}. \tag{37}$$

There are other ways in which this ϕ may be expressed, viz.,

$$\phi = c^{-1}(c\mu^{-1})^{\frac{1}{2}} = \mu^{-1}(\mu c^{-1})^{\frac{1}{2}} = (\mu^{-1}c)^{\frac{1}{2}}c^{-1} = (c^{-1}\mu)^{\frac{1}{2}}\mu^{-1}, \tag{38}$$

all of which lead to
$$\mu\phi c\phi = 1. \tag{39}$$

If this ϕ is self-conjugate, we see, by (17) and (35), that its use in (20) brings us to

$$q\,\frac{q}{\mu^{-1}-\dfrac{c^{-1}}{[\sigma^{-1}](qcq)}} = 0 = q\,\frac{q}{c^{-1}-\dfrac{\mu^{-1}}{[\mu^{-1}](q\mu q)}}. \tag{40}$$

That is, the strain converts the first of (10) to the first of (40), and the second of (10) to the second of (40). But the first of (40) is the same as the second of (10) with μ and c inverted, and the second of (40) is the same as the first of (10) with the same inversions. In other words, the strain has converted the duplex wave-surface to its corresponding index-surface. Observe that the crossing over from first to second form is an essential part of the demonstration, which is the reason I have employed two forms.

In full, the strainer to be applied to r of the wave-surface to produce the vector s of the index-surface (or q in (40)) is

$$\frac{\phi}{[\phi]} = [c^{\frac{1}{2}}][\mu^{\frac{1}{2}}]c^{-1}(c\mu^{-1})^{\frac{1}{2}}. \tag{41}$$

But to complete the demonstration it should be shown that this strain is pure, because we have just assumed $\phi = \phi'$ in equation (20) to obtain (40). Now the purity of this strain is not obvious in the form (41), nor in any of the similar forms in (38). But we may change the expression for ϕ to such a form as will explicitly show its purity. Thus, we have

$$c\mu^{-1} = c^{\frac{1}{2}}.c^{\frac{1}{2}}\mu^{-1}c^{\frac{1}{2}}.c^{-\frac{1}{2}},$$

identically, and this may be expanded to

$$c\mu^{-1} = c^{\frac{1}{2}}(c^{\frac{1}{2}}\mu^{-1}c^{\frac{1}{2}})^{\frac{1}{2}}c^{-\frac{1}{2}}c^{\frac{1}{2}}(c^{\frac{1}{2}}\mu^{-1}c^{\frac{1}{2}})^{\frac{1}{2}}c^{-\frac{1}{2}},$$

the right member reducing to the left by obvious cancellations. Therefore

$$(c\mu^{-1})^{\frac{1}{2}} = c^{\frac{1}{2}}(c^{\frac{1}{2}}\mu^{-1}c^{\frac{1}{2}})^{\frac{1}{2}}c^{-\frac{1}{2}},$$

by taking the square root. So, finally,

$$\phi = c^{-1}(c\mu^{-1})^{\frac{1}{2}} = c^{-\frac{1}{2}}(c^{\frac{1}{2}}\mu^{-1}c^{\frac{1}{2}})^{\frac{1}{2}}c^{-\frac{1}{2}}. \tag{42}$$

This is of the form $\phi_1\phi_2\phi_1$, where ϕ_1 is pure. Its conjugate is there-fore $\phi_1\phi'_2\phi_1$. This reduces to ϕ itself if ϕ_2 is pure. But ϕ_2 is pure, because it is also of the form $\theta_1\theta_2\theta_1$, where θ_1 and θ_2 are both pure. So our single strain depending on ϕ is pure.

Substitution of three successive Pure Strains for one.   Two ways.

8. This is dry mathematics. But it is at once endowed with in-terest if we consider the meaning of the expression of the strain ϕ as equivalent to the three successive strains ϕ_1, ϕ_2, and ϕ_1. First, the strain

$$q = \frac{\phi_1}{[\phi_1]}\, r = \frac{c^{-\frac{1}{2}}}{[c^{-\frac{1}{2}}]}\, r \qquad (43)$$

converts the duplex wave-surface to a simplex surface. This was done before, equation (28). Next, the strain

$$p = \frac{\phi_2}{[\phi_2]}\, q = \frac{(c^{\frac{1}{2}}\mu^{-1}c^{\frac{1}{2}})^{\frac{1}{2}}}{[c^{\frac{1}{2}}][\mu^{-\frac{1}{2}}]}\, q \qquad (44)$$

converts the simplex surface q to another simplex surface whose vector is p, and which is the index-surface corresponding to the wave-surface q. This strain (44) is, in fact, the same as (33), and the result is

$$p\,\frac{p}{1 - \dfrac{\lambda^{-1}}{[\lambda^{-1}]\,(p\lambda p)}} = 0 = p\,\frac{p}{\lambda^{-1} - \dfrac{1}{p^2}}, \qquad (45)$$

where $\lambda = c^{-\frac{1}{2}}\mu c^{-\frac{1}{2}}$. Finally, the strain

$$s = \frac{\phi_1}{[\phi_1]}\, p = \frac{c^{-\frac{1}{2}}}{[c^{-\frac{1}{2}}]}\, p \qquad (46)$$

converts the simplex surface p to a duplex surface s, which is the reciprocal of the original duplex wave-surface, the result being (40).

The interchangeability of μ and c shows that we may also strain from r to s by a second set of three successive pure strains, thus,

$$\phi = \mu^{-\frac{1}{2}}(\mu^{\frac{1}{2}}c^{-1}\mu^{\frac{1}{2}})^{\frac{1}{2}}\mu^{-\frac{1}{2}}. \qquad (47)$$

This is the same as first straining the surface r to the simplex surface (26) ; then inverting the latter, which brings us to the simplex sur-face (32) ; and finally straining the last to the duplex surface s.

Transformation of Characteristic Equation by Strain.

9. In connexion with the above transformations, it may be worth while to show how they work out when applied to the characteristic equation itself of **E** or **H**. Thus, take the form (7), or

$$-c\ddot{\mathbf{E}} = V\nabla\mu^{-1}V\nabla\mathbf{E}, \tag{48}$$

and let
$$\mathbf{r} = f\mathbf{r}', \qquad \nabla = f^{-1}\nabla', \qquad \mathbf{E} = f^{-1}\mathbf{E}', \tag{49}$$

so that (48) becomes

$$-cf^{-1}\ddot{\mathbf{E}}' = Vf^{-1}\nabla'\mu^{-1}Vf^{-1}\nabla'f^{-1}\mathbf{E}'. \tag{50}$$

Now employ Hamilton's formula

$$V\mathbf{mn} = \frac{\phi V\phi\mathbf{m}\phi\mathbf{n}}{[\phi]}, \tag{51}$$

ϕ being here any self-conjugate operator. Take $\phi = f^{-1}$, and we transform (50) to

$$-cf^{-1}\mathbf{E}' = Vf^{-1}\nabla'\mu^{-1}fV\nabla'\mathbf{E}' \times [f^{-1}] \tag{52}$$

$$= Vf^{-1}\nabla'f^{-1}(f\mu^{-1}f)\,V\nabla'\mathbf{E}' \times [f^{-1}]. \tag{53}$$

In this use Hamilton's formula again, with $\phi = f^{-1}$, and we obtain

$$= fV\nabla'(f\mu^{-1}f)\,V\nabla'\mathbf{E}' \times [f^{-1}]^2. \tag{54}$$

Or, more conveniently written,

$$-\frac{(f^{-1}cf^{-1})}{[f^{-1}]}\,\ddot{\mathbf{E}}' = V\nabla'\frac{(f\mu^{-1}f)}{[f]}\,V\nabla'\mathbf{E}'. \tag{55}$$

So far, f is any pure strainer; we can now make various specializations. For example, to get rid of μ^{-1} from the right side of (48), and substitute c. Take

$$\frac{f\mu^{-1}f}{[f]} = c, \quad \text{then} \quad \frac{f^{-1}cf^{-1}}{[f^{-1}]} = \mu^{-1}, \tag{56}$$

which brings (55) to the form

$$-\mu^{-1}\ddot{\mathbf{E}}' = V\nabla'cV\nabla'\mathbf{E}', \tag{57}$$

which should be compared with the other characteristic, that of $\mathbf{H}$, which is (8), or

$$-\mu\ddot{\mathbf{H}} = V\nabla c^{-1}V\nabla\mathbf{H}. \tag{58}$$

The above process is analogous to our transformation from the duplex wave-surface to its reciprocal. As then, we have an inversion of operators and also a crossing over from one form to another.

Derivation of Index Equation from Characteristic.

10. We may also, in conclusion, exhibit how the index-surface arises from the characteristic, when done in terms of ∇ up to the last

moment. Start from the last equation (58). Hamilton's formula (51) makes it become

$$-[c]\mu\mathbf{H} = \nabla\nabla\nabla c\nabla c\mathbf{H}. \tag{59}$$

The elementary formula in vector algebra,

$$\nabla a\nabla bc = b(ca) - c(ab), \tag{60}$$

transforms (59) to

$$-[c]\mu\ddot{\mathbf{H}} = c\nabla(\nabla c\mathbf{H}) - (\nabla c\nabla)c\mathbf{H}, \tag{61}$$

or

$$\left[(\nabla c\nabla)c - [c]\mu\frac{d^2}{dt^2}\right]\mathbf{H} = c\nabla(\nabla c\mathbf{H}), \tag{62}$$

from which

$$\mu\mathbf{H} = \mu\left[(\nabla c\nabla)c - [c]\mu\frac{d^2}{dt^2}\right]^{-1}c\nabla(\nabla c\mathbf{H}). \tag{63}$$

So far we have merely a changed form of the characteristic. But the induction $\mu\mathbf{H}$ is circuital. Therefore, taking the divergence of (63), we obtain

$$0 = \nabla\mu\left[(\nabla c\nabla)c - [c]\mu\frac{d^2}{dt^2}\right]^{-1}c\nabla(\nabla c\mathbf{H}), \tag{64}$$

or, which is the same,

$$0 = \nabla\left[(\nabla c\nabla)\mu^{-1} - [c]c^{-1}\frac{d^2}{dt^2}\right]^{-1}\nabla(\nabla c\mathbf{H}). \tag{65}$$

Here $\nabla c\mathbf{H}$ is the divergence of $c\mathbf{H}$. It is the same as $(c\nabla)\mathbf{H}$.

Now (65) only differs from the velocity equation (for plane waves) in containing ∇ instead of the unit normal $\mathbf{N}$ and d^2/dt^2 instead of v^2, v being the wave-velocity. Thus, let

$$\mathbf{H} = f(z - vt),$$

then we shall have

$$v^2\nabla^2\mathbf{H} = \frac{d^2}{dt^2}\mathbf{H},$$

where, however, ∇^2 is specialized, being only ∇_z^2 or d^2/dz^2. We therefore put $v^2\nabla_z^2$ for d^2/dt^2 and $\mathbf{N}\nabla_z$ for ∇ in equation (65), thus making

$$0 = \mathbf{N}\nabla_z\left[(\mathbf{N}\nabla_z c\mathbf{N}\nabla_z)\mu^{-1} - [c]c^{-1}v^2\nabla_z^2\right]^{-1}\mathbf{N}\nabla_z(\mathbf{N}\nabla_z c\mathbf{H}) \tag{66}$$

We may now cancel out all the ∇_z's except the last, making

$$0 = \mathbf{N}\left[(\mathbf{N}c\mathbf{N})\mu^{-1} - [c]c^{-1}v^2\right]^{-1}\mathbf{N}(\mathbf{N}\nabla_z c\mathbf{H}). \tag{67}$$

Now throw away the operand $N_{V_3}cH$, and we get the velocity equation pure and simple, and the index equation (3) then comes by $s = Nv^{-1}$.

But, although the above manipulation of the characteristic equation has some analytical interest, the process cannot be always recommended on the score of simplicity. It is, on the contrary, usually easier and simpler to work upon the component equations upon which the characteristic is founded.

Presents, January 18, 1894.

Transactions.

Baltimore :—Johns Hopkins University. Circulars. Vol. XIII. No. 108. 4to. *Baltimore* 1893; Studies in Historical and Political Science. Eleventh Series. Nos. 11—13. 8vo. *Baltimore* 1893. The University.

Medical and Chirurgical Faculty of the State of Maryland. Transactions of the Ninety-fifth Annual Session. 8vo. *Baltimore* 1893. The Faculty.

Berkeley :—University of California. [University Publications for the year 1892–93.] 8vo. 1892–93. The University.

Berlin :—Deutsche Chemische Gesellschaft. Berichte. 1893. Nos. 9—18. 8vo. *Berlin.* The Society.

Brussels :—Académie Royale de Médecine. Bulletin. Tome VIII. Nos. 5—9. 8vo. *Bruxelles* 1893. The Academy.

Académie Royale des Sciences. Bulletin. Tome XXVI. Nos. 5—11. 8vo. *Bruxelles* 1893. The Academy.

Bucharest :—Societătii de Sciinte Fizice. Buletinul. Anul II. Nos. 9—10. 8vo. *Bucuresci* 1893. The Society.

Buitenzorg :—'s Lands Plantentuin. Mededeelingen. Nos. 8—9. 8vo. *Batavia* 1891. The Director.

Cambridge :—Cambridge Philosophical Society. Proceedings. Vol. VIII. Part 2. 8vo. *Cambridge* 1894. The Society.

Cambridge, Mass. :—Museum of Comparative Zoology. Bulletin. Vol. XXV. Nos. 2—3. 8vo. *Cambridge* 1893.
The Museum.

Copenhagen :—Kongelige Danske Videnskabernes Selskab. Skrifter. Bd. VII. Nos. 8—9. 4to. *Kjöbenhavn* 1893 ; Oversigt. 1893. No. 2. 8vo. *Köbenhavn.* The Society.

Cracow :—Académie des Sciences. Bulletin International. Novembre, 1893. 8vo. *Cracovie* 1893. The Academy.

Davenport :—Academy of Natural Sciences. Proceedings. Vol. V. Part 2. 8vo. *Davenport, Iowa* 1893. The Academy.

Dublin :—Royal Irish Academy. Transactions. Vol. XXX. Parts

Transactions (*continued*).

6, 9. 4to. *Dublin* 1893; Proceedings. Third Series. Vol.
III. No. 1. 8vo. *Dublin* 1893. . The Academy.

Dulwich:—Science Society, Dulwich College. Report, 1892–93.
8vo. *Sydenham* 1893. The Society.

Edinburgh :—Geological Society. Transactions. Vol. V. Part 4.
8vo. *Edinburgh* 1888. The Society.

Royal Scottish Society of Arts. Transactions. Vol. XIII.
Part 3. 8vo. *Edinburgh* 1893. The Society.

Florence :—Biblioteca Nazionale Centrale. Bolletino. 1893.
Num. 180—192. 8vo. *Firenze.* The Library.

Frankfort-on-the-Oder :—Naturwissenschaftlicher Verein. Helios.
Jahrg. XI. Nos. 6—9. 8vo. *Frankfort a.O.* 1893; Societatum
Litteræ. Jahrg. VII. Nos. 8—12. 8vo. *Frankfort a.O.* 1893.
The Society.

Geneva :—Société de Physique et d'Histoire Naturelle. Mémoires.
Tome XXXI. Partie 2. 4to. *Genève* 1892–93.
The Society

Glasgow :—Philosophical Society. Proceedings. Vol. XXIV.
8vo. *Glasgow* 1893. The Society.

Irkutsk :—East-Siberian Section, Imperial Russian Geographical
Society. Izvestiya. Vol. XXIV. Nos. 3—4. [*Russian.*] 8vo.
Irkutsk 1893. The Society.

Jena :—Medicinisch-Naturwissenschaftliche Gesellschaft. Jena-
ische Zeitschrift für Naturwissenschaft. Bd. XXVIII. Heft 2.
8vo. *Jena* 1893. The Society.

Kew :—Royal Gardens. Bulletin of Miscellaneous Information.
1893. Nos. 82—83. 1894. Appendix I. 8vo. *London* 1893–94.
The Director.

Leipsic:—Königl. Sächs. Gesellschaft der Wissenschaften. Abhand-
lungen (Math.-Phys. Classe). Bd. XX. Nos. 3—4. 8vo.
Leipzig 1893. The Society.

Liége:—Société Géologique de Belgique. Annales. Tome XX.
Livr. 2. 8vo. *Liége* 1892–93. The Society.

London :—British Astronomical Association. Journal. Vol. IV.
No. 1. 8vo. *London* 1893. The Association.

Chemical Society. Journal. July—December. 8vo. *London;*
Proceedings. Nos. 127—130. 8vo. *London* 1893.
The Society.

East India Association. Journal. Vol. XXVI. No. 1. 8vo.
London 1893. The Association.

Entomological Society. Transactions. 1893. Part 4. 8vo.
London 1893. The Society.

Geological Society. Abstracts of the Proceedings. Nos. 611—
615. 8vo. [*London* 1893.] . The Society.

Transactions (*continued*).

Imperial Institute. Annual Report, 1893. 8vo. *London* 1893.
The Institute.

Institution of Civil Engineers. Abstracts of the Proceedings. Session 1893-94. Nos. 1—5. 8vo. [*London.*]
The Institution.

Institution of Electrical Engineers. Journal. Vol. XXII. No. 107. 8vo. *London* 1893.   The Institution.

Institution of Mechanical Engineers. Proceedings. 1893. No. 3. 8vo. *London.*   The Institution.

Mineralogical Society. The Mineralogical Magazine. Vol. X No. 47. 8vo. *London* 1893.   The Society.

Odontological Society. Transactions. Vol. XXVI. Nos. 1—2. 8vo. *London* 1893.   The Society.

Pathological Society. Transactions. Vol. XLIV. 8vo. *London* 1893.   The Society.

Pharmaceutical Society of Great Britain. Pharmaceutical Journal and Transactions. July—December, 1893. 8vo. *London.*
The Society.

Photographic Society. Journal and Transactions. Vol. XVIII. No. 4. 8vo. *London* 1893.   The Society.

Royal Agricultural Society. Journal. Third Series. Vol. IV Part 4. 8vo. *London* 1893.   The Society.

Royal Astronomical Society. Monthly Notices. Vol. LIII. Nos. 6—9. Vol. LIV. No. 1. 8vo. *London* 1893.
The Society.

Royal Geographical Society. The Geographical Journal. July —December, 1893. 8vo. *London.*   The Society

Royal Institute of British Architects. Journal of Proceedings. July—December, 1893. 4to. *London.*   The Institute.

Royal Institution of Great Britain. Reports of the Weekly Evening Meetings. January—June, 1893. 8vo. *London.*
The Institution.

Royal Microscopical Society. Journal. 1893. Part 6. 8vo. *London* 1893.   The Society.

Royal Statistical Society. Journal. Vol. LVI. Part 4. 8vo. *London* 1893.   The Society.

Royal United Service Institution. Journal. Vol. XXXVII. No. 190. 8vo. *London* 1893.   The Institution.

Society of Arts. Journal. July—December, 1893. 8vo. *London.*
The Society.

Society of Chemical Industry. Journal. Vol. XII. Nos. 6—11. 8vo. *London* 1893.   The Society.

Victoria Institute. Journal. Vol. XXVII. Part 1. *London* 1893.   The Institute.

Transactions (*continued*).

Madison :—Wisconsin Academy of Science, Arts, and Letters. Vol. IX. Part 1. 8vo. *Madison* 1893. The Academy.

Manchester :—Geological Society. Transactions. Vol. XXII. Part 13. 8vo. *Manchester* 1893. The Society.

Mexico :—Sociedad Científica "Antonio Alzate." Memorias y Revista. Tomo VII. Nos. 3—4. 8vo. *México* 1893.
The Society.

Moscow :—Société Impériale des Naturalistes. Bulletin. Année 1893. Nos. 2—3. 8vo. *Moscou* 1893. The Society.

New York :—Academy of Sciences. Annals. Vol. VIII. Nos. 1—3. 8vo. *New York* 1893; Transactions. Vol. XII. 8vo. *New York* [1893]. The Academy.

American Museum of Natural History. Bulletin. Vol. V. Pp. 305—336. 8vo. [*New York*] 1893.
The Museum.

Paris :—Académie des Sciences. Comptes Rendus. Juillet— Décembre, 1893. 4to. *Paris;* Bulletin du Comité International Permanent pour l'Exécution Photographique de la Carte du Ciel. Tome II. Fasc. 2. 4to. Paris 1893.
The Academy.

École Normale Supérieure. Annales. Tome X. No. 12. 4to. *Paris* 1893. The School.

Société de Biologie. Comptes Rendus. Juillet—Décembre, 1893. 8vo. *Paris.* The Society.

Société de Géographie. Comptes Rendus des Séances. 1893. Nos. 12—18. 8vo. *Paris.* The Society.

Société d'Encouragement pour l'Industrie Nationale. Bulletin. Mai—Juillet, 1893. 4to. *Paris;* Compte-Rendu des Séances. Juin—Décembre, 1893. 8vo. *Paris.* The Society.

Société Française de Physique. Séances. Avril—Juillet, 1893. 8vo. *Paris* 1893; Bulletin Bimensuel. 1892–93. Nos. 26— 28, 30—33. 8vo. *Paris.* The Society.

Société Géologique de France. Compte-Rendu des Séances. 1893. Nos. 13—18. 8vo. [*Paris.*] The Society.

Société Mathématique. Bulletin. Tome XXI. Nos. 7—8. 8vo. *Paris.* The Society.

Société Philomathique. Compte-Rendu des Séances. 1892–93. Nos. 17—18, 20. 1893–94. Nos. 1—5. 8vo. *Paris.*
The Society.

Philadelphia :—Academy of Natural Sciences. Proceedings. 1893. Parts 1—2, and Pp. 217—312, 345—376. 8vo. *Philadelphia.*
The Academy.

Franklin Institute. Journal. July—December, 1893. 8vo. *Philadelphia.* The Institute.

Transactions (*continued*).

Pisa:—Società Toscana di Scienze Naturali. Processi Verbali. Vol. VIII. Pp. 233—241. 8vo. *Pisa.* The Society.

Rome:—Reale Accademia dei Lincei. Rendiconti. Serie 5. Vol. II. Semestre 1. Fasc. 10—12. Semestre 2. Fasc. 1—11. 8vo. *Roma* 1893. The Academy.

San Francisco:—Californian Academy of Sciences. Proceedings. Second Series. Vol. III. Part 2. 8vo. *San Francisco* 1893; Occasional Papers. No. 4. 8vo. *San Francisco* 1893.

The Academy.

Santiago:—Sociedad Nacional de Mineria. Boletin. Año. X. Nos. 59—60. 4to. *Santiago de Chile* 1893. The Society. Société Scientifique de Chili. Actes. Tome III. Livr. 1—2. 8vo. *Santiago* 1893. The Society.

Stavanger:—Museum. Aarsberetning. 1892. 8vo. *Stavanger* 1893. The Museum.

Stockholm:—Kongl. Svenska Vetenskaps Akademie. Bihang till Handlingar. Band 18. 8vo. *Stockholm* 1893; Öfversigt. Årg. 50. No. 8. 8vo. *Stockholm* 1893. The Academy.

Sydney:—Linnean Society of New South Wales. Proceedings. Vol. VIII. Part 1. 8vo. *Sydney* 1893; Abstract of Proceedings. May—November, 1893. 8vo. *Sydney;* The Macleay Memorial Volume. Edited by J. J. Fletcher. 4to. *Sydney* 1893. The Society.

Tōkyō:—Imperial University of Japan. Calendar. 1892–93. 8vo. *Tōkyō* 1893; Mittheilungen aus der Medicinischen Facultät. Bd. II. No. 1. 4to. *Tokio* 1893. The University.

Toronto:—University. Calendar. 1893-94. 8vo. *Toronto* 1893. The University.

Turin:—Reale Accademia delle Scienze. Memorie. Tome XLIII. 4to. *Torino* 1893. The Academy.

Vienna:—Kais. Akademie der Wissenschaften. Sitzungsberichte. Bd. CII. Abth. 2b. Heft 8. 8vo. *Wien* 1893; Anzeiger. Jahrg. 1893. Nos. 23—27. 8vo. *Wien* 1893. The Academy.

Washington:—Smithsonian Institution. Miscellaneous Collections. Vol. XXXIV. 8vo. *Washington* 1893.

The Institution.

Surgeon-General's Office. Index-Catalogue of the Library. Vol. XIV. 4to. *Washington* 1893. The Surgeon-General.

Observations and Reports.

Bombay:—Meteorological Office. Brief Sketch of the Meteorology of the Bombay Presidency in 1892-93. 4to. *Bombay.*

The Office.

Observations and Reports (*continued*).

Brisbane:—Registrar-General's Office. Vital Statistics, 1892. Folio. *Brisbane* 1893. The Registrar-General.

Calcutta:—Meteorological Department, Government of India. Monthly Weather Review. July, 1893. 4to. *Calcutta* 1893; Observations made at Seven Stations in India. July, 1893. 4to. [*Calcutta.*] The Department.

Cambridge, Mass. :—Astronomical Observatory of Harvard College. Forty-eighth Annual Report of the Director. 8vo. *Cambridge* 1893. The Observatory.

Canada :—Geological Survey. Annual Report. Vol. V. 8vo. *Ottawa* 1893. The Survey.

Chemnitz:—Königl. Sächs. Meteorologisches Institut. Jahrbuch. Jahrg. X. Abth. 3. Hälfte 2. 4to. *Chemnitz* 1893. The Institute.

Chicago :—Royal Commission for the Chicago Exhibition, 1893. Official Catalogue of the British Section. 8vo. *London* 1893. Marine Biological Association of the United Kingdom.

Coimbra :—Observatorio Meteorologico e Magnetico. Observações Meteorologicas e Magneticas. 1892. Folio. *Coimbra* 1893. The University, Coimbra.

Dorpat :—Meteorologisches Observatorium. Meteorologische Beobachtungen. Bd. VI. Heft 2. 8vo. *Jurjew* 1893. The Observatory.

Dublin :—General Register Office. Weekly Return of Births and Deaths. July—December, 1893. 8vo. *Dublin.* The Office.

France:—Service des Topographies Souterraines. Études des Gîtes Minéraux de la France. Bassin Houillier et Permien d'Autun et d'Épinac. Fasc. 4. Atlas. 4to. *Paris* 1893. The Service.

London:—Medical Department of the Navy. Statistical Report of the Health of the Navy for the Year 1892. 8vo. *London* 1893. The Department.

Meteorological Office. Daily Weather Report. July—December, 1893. 4to. *London;* Weekly Weather Report. Vol. X. Nos. 44—52. 4to. *London;* Report of the Meteorological Council to the Royal Society for the year ending 31st March, 1893. 8vo. *London* 1893. The Office.

Melbourne :—Office of the Government Statist. General Report of the Census of Victoria, 1891. By H. H. Hayter. 4to. *Melbourne* 1893. The Government Statist.

New South Wales:—Geological Survey. Records. Vol. III. Part 4. 8vo. *Sydney* 1893. Department of Mines, Sydney.

Observations and Reports (*continued*).

Paris:—Service Hydrométrique du Bassin de la Seine. Observations sur les Cours d'Eau et de la Pluie. Année 1892. Folio. *Versailles*; Résumé des Observations Centralisées. Année 1892. 8vo. *Versailles* 1893.   The Service.

Rio de Janeiro :—Observatorio. Annuario. 1893. 8vo. *Rio de Janeiro* 1893.   The Observatory.

San Francisco:—California State Mining Bureau. Eleventh Report. 8vo. *Sacramento* 1893.   The Bureau.

Spain:—Comisión del Mapa Geológico de España. Mapa Geológico de España. 10 Sheets.   The Commission.

Sydney :—Observatory. Meteorological Observations. June, 1893. 8vo. [*Sydney.*]   The Observatory.

Upsala:—Observatoire. Observations du Magnétisme Terrestre faites à Upsala pendant l'Exploration Internationale des Régions Polaires en 1882–83. 4to. *Stockholm* 1893.

Royal Swedish Academy of Sciences, Stockholm.

Washington :—U.S. Department of Agriculture. Experiment Station Record. Vol. V. No. 1. 8vo. *Washington* 1893; Weather Bureau. Monthly Weather Review. September, 1893. 8vo. *Washington;* Report of the Ohio Weather and Crop Service. October—November, 1893. 8vo. *Norwa'k.*

The Department.

U.S. Patent Office. Official Gazette. Vol. LXV. Nos. 4—13. 8vo. *Washington* 1893. With Alphabetical Lists of Patentees and Inventions.   The Office.

Journals.

American Chemical Journal. Vol. XV. Nos. 6—8. 8vo. *Baltimore.*   The Editor.

American Journal of Mathematics. Vol. XV. Nos. 3—4. 4to. *Baltimore* 1893.   The Editors.

American Journal of Science. July—December, 1893. 8vo. *New Haven.*   The Editors.

Analyst (The) July—December, 1893. 8vo. *London.*

Society of Public Analysts.

Annalen der Physik und Chemie. 1893. Nos. 7—12. 8vo. *Leipzig;* Beiblätter. 1893. Nos. 6—11. 8vo. *Leipzig.*

The Editors.

Annales des Mines. 1893. Livr. 6—11. 8vo. *Paris* 1893.

École des Mines, Paris.

Annales des Ponts et Chaussées. 1893. Nos. 3—9. 8vo. *Paris.*

Ministère de Travaux Publics, Paris.

Asclepiad (The) Vol. X. No. 39. 8vo. *London* 1893.

Sir B. W. Richardson, F.R.S.

Journals (*continued*).

Astronomie (L') Août—Décembre, 1893. 8vo. *Paris.*
<div align="right">The Editor.</div>

Astronomy and Astro-Physics. December, 1893. 8vo. *Northfield,*
Minn. <div align="right">The Editors.</div>

Athenæum (The) July—December. 1893. 4to. *London.*
<div align="right">The Editor.</div>

Boletin de Minas Industria y Construcciones. Año IX. No. 10.
4to. *Lima* 1893. Escuela de Ingenieros, Lima.

Builder (The) July—December. 1893. Folio. *London.*
<div align="right">The Editor.</div>

Chemical News. July—December, 1893. 8vo. *London.*
<div align="right">Mr. W. Crookes, F.R.S.</div>

Cosmos. Juillet—Décembre, 1893. 8vo. *Paris.*
<div align="right">M. l'Abbé Valette.</div>

Educational Times (The) July—December, 1893. 4to. *London.*
<div align="right">College of Preceptors.</div>

Electrical Engineer (The) July—December, 1893. Folio.
London. <div align="right">The Editor.</div>

Electrical Review (The) July—December, 1893. Folio. *London.*
<div align="right">The Editor.</div>

Electrician (The) July—December, 1893. Folio. *London.*
<div align="right">The Editor.</div>

Électricien (L') Juillet—Decémbre, 1893. Folio. *Paris.*
<div align="right">The Editor</div>

Fisherman's (The) Nautical Almanac and Tide Tables. 1894. 8vo.
Grimsby 1893. <div align="right">The Editor.</div>

Horological Journal. Vol. XXXVI. No. 425. 8vo. *London*
1893. <div align="right">British Horological Institute.</div>

Industries and Iron. July—December, 1893. 4to. *London.*
<div align="right">The Editor.</div>

Meteorologische Zeitschrift. 1893. Heft 7—11. Small folio.
Wien. Oesterreichische Gesellschaft für Meteorologie.

Morphologisches Jahrbuch. Bd. XX. Heft 4. 8vo. *Leipzig*
1893. <div align="right">The Editor.</div>

Morskoi Sbornik. 1893. Nos. 7—9. [*Russian.*] 8vo. *St.*
Petersburg. Compass Observatory, Cronstadt.

Nature. July—December, 1893. Roy. 8vo. *London.*
<div align="right">The Editor.</div>

Nature Notes. Vol. V. No. 49. 8vo. *London* 1894.
<div align="right">Selborne Society.</div>

New York Medical Journal. July—December, 1893. 4to. *New*
York. <div align="right">The Editor.</div>

Notes and Queries. July—December, 1893. 4to. *London.*
<div align="right">The Editor.</div>

Journals (*continued*).

    Observatory (The)   July—December, 1893.   8vo.   *London.*
                                              The Editors.
    Revue Générale des Sciences.   Juillet—Décembre, 1893.   8vo.
      Paris.   The Editor.
    Revue Scientifique.   Juillet—Décembre, 1893.   4to.   *Paris.*
                                                The Editor.
    Symons's Monthly Meteorological Magazine.   July—December,
      1893.   8vo.   *London.*   Mr. G. J. Symons, F.R.S.
    Technology Quarterly.   Vol. VI.   No. 2.   8vo.   *Boston* 1893.
                                  Institute of Technology.
    Zeitschrift für Biologie.   Bd. XI.   Heft 3—4.   Bd. XII.   Heft
      1—2.   8vo.   *München* 1893.   The Editors.

Brodie (Rev. P. B.)   Notes on the Eocene Tertiary Insects of the
    Isle of Wight.   8vo.   1893.   The Author.
Browning (J.)   Our Eyes, and how to preserve them from Infancy
    to Old Age.   8vo.   *London* 1892.   The Author.
Dawson (Sir J. W.), F.R.S.   The Canadian Ice Age: being Notes on
    the Pleistocene Geology of Canada, with especial reference to
    the Life of the Period and its Climatal Conditions.   8vo.
    Montreal 1893.   The Author.
Gamgee (A.), F.R.S.   A Text-book of the Physiological Chemistry
    of the Animal Body.   Vol. II.   8vo.   *London* 1893.
                                                  The Author.
Gore (G.), F.R.S.   The Decomposition of Liquids by Contact with
    Powdered Silica, &c.   8vo.   *Birmingham* 1893.
                                                The Author.
Grant (J. A.)   Abstract of the Code of Customary Law for the
    Amritsar District.   Vol. XI.   8vo.   *Lahore* 1893.
                                           The India Office.
Hooker (Sir J. D.), F.R.S., and B. D. Jackson.   Index Kewensis; an
    Enumeration of the Genera and Species of Flowering Plants
    from the time of Linnæus to the year 1885.   Parts 1—2.   4to.
    Oxford 1893.   Sir Joseph Hooker, F.R.S.
Keeler (J. E.)   Physical Observations of Mars made at the Allegheny
    Observatory in 1892.   4to.   *London* 1893.   The Author.
Lütken (C. F.)   E Museo Lundii.   Bind II.   Halvbind 1.   4to.
    Kjöbenhavn 1893.   Royal Danish Academy of Sciences.
Salazar (A. E.) i Q. Newman.   El Ielo qe se qonsume en Balparaiso.
    8vo.   *Santiago de Chile* 1893.   The Authors.
Sidgreaves (W.)   The Physical Constitution of the Sun.   8vo.
    [1893.]   The Author.

Wardle (T.) On the Relation of Design to such Craft Teaching as may be undertaken by Technical Schools. 4to. *Manchester* 1893. The Author.

————————————

Photogravure Portrait of Professor Michael Foster, Sec. R.S., after a painting by H. Herkomer, R.A.

The Subscribers to the Foster Portrait Fund,
Trinity College, Cambridge.

January 25, 1894.

Sir JOHN EVANS, K.C.B., D.C.L., LL.D., Vice-President and Treasurer, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "On Intra-cranial Pressure. Preliminary Note." By LEONARD HILL, M.B., Assistant Professor of Physiology, University College, London. Communicated by Professor BURDON SANDERSON, F.R.S. Received November 16, 1893.

(From the Physiological Laboratories of Oxford and University College.)

My purpose in the following note is to submit to the Royal Society the results of experiments, made during the past year, relating to the "intra-cranial pressure" (*i.e.*, the pressure to which the brain is normally exposed in the cranial cavity), and the changes which can be produced in it by alterations of the form and diminution of the capacity of the cranial cavity.

The experiments were undertaken at the suggestion of Professor Burdon Sanderson, and have been carried out with his help and criticism.

The animals employed were cats or dogs. Ether, chloroform, and morphia were used as anæsthetics.

Methods of Research.

Methods of Producing Alterations of Pressure within the Subdural Space.—

a. The skull is trephined in the parietal region, the dura mater freely divided, the trephine hole "wormed" with an ordinary

mechanic's tap, and a brass tube of about 2 inches in length screwed into the hole. This tube is connected with a burette containing salt solution at the temperature of the animal. A clip is interposed between the burette and the brass tube, and the burette connected with a pressure apparatus.

By this method salt solution can be driven into the subdural space in measured amounts and at varying rates.

β. If, before introducing the brass tube, a bag of very thin india-rubber is tied on to the end of it (the arrangement being otherwise the same), measured amounts of salt solution can be repeatedly introduced or withdrawn from the bag within the subdural space.

2. *Measurement of the Normal Intra-cranial Pressure or Cerebral Tension.*—

ᴁ. A trephine hole is made, "wormed," and filled with warm salt solution. A piece of brass tube is screwed in, over the end of which a membrane of very thin india-rubber has been tied. The brass tube is connected with the intervention of a piece of fine-bored glass tubing with a T-piece, one branch of which leads to a pressure bottle, the other to a mercurial manometer. The apparatus is completely filled with water, excepting that a bubble of air is introduced within the glass tube so as to act as an index.

The normal position of the air index is marked on the glass tube before the apparatus is screwed into the trephine hole. On screwing the apparatus in, the air index, which is at first forced out, is brought back again to the normal position by raising the pressure bottle. The manometer records the normal intra-cranial pressure.

β. A trephine hole is made and "wormed," and the dura mater is then freely divided.

The measuring apparatus is filled with 0·6 per cent. salt solution, instead of water, and an air index is introduced within the glass tubing. No membrane is placed upon the end of the brass tube, so that when the tube is screwed in its cavity freely communicates with the subdural space. The pressure bottle is now raised till the air index begins to move inwards. The manometer records the pressure which is necessary to balance the normal intra-cranial pressure. Any excess drives salt solution into the subdural space.

3. *Measurement of the Variations of Intra-cranial Pressure produced by the above Methods* (1 α and β).—

With the measuring apparatus (2 α) the variations can be accurately measured and recorded graphically. For when by increase of intra-cranial pressure the air index is displaced outwards it can be brought back again to its initial position by raising the pressure bottle to the required amount, and when by decrease of intra-cranial pressure the air index is sucked inwards it can, in like manner, be brought back again to the mark by lowering the pressure bottle. In

either case, the pressure required, as indicated by the mercurial manometer, is the intra-cranial pressure at the time.

4. *Methods of obtaining Records of the Cerebral Venous Pressure.*— The superior longitudinal sinus, with its tributaries, in the dog opens into a large venous cavity within the occipital protuberance; the transverse sinuses lying within the bony tentorium cerebelli lead out of this cavity. Part of the blood finds its exit by the post-glenoid foramen, and reaches the external jugular vein, but a very large portion passes into the large sinuses which run down the vertebral canal.

The methods are as follows :—

α. A hole is drilled into the venous cavity within the occipital protuberance. Into the hole a tube is fixed, filled with sodium sulphate solution. The tube is connected with a water manometer.

β. The skull is opened over the occipital protuberance, and a venous cannula passed into the superior longitudinal sinus against the direction of the blood flow. The cannula is connected with a water manometer. This method gives the venous pressure with obstructed flow.

In either of these methods the manometer can be connected with a light and delicate tambour, and the venous pressure recorded.

Records of the blood pressure in the carotid artery, and of the respiration, were taken simultaneously with the records of intra-cranial pressure.

By the method of "worming" the trephine holes before screwing in the brass tubes the connexions were made (as tested) absolutely air tight. The delicacy of the measuring apparatus was tested on an artificial scheme, and found to be perfect.

Results.

1. The normal intra-cranial pressure scarcely ever exceeds 10 mm. Hg. (Method 2 α and β.)

2. The normal cerebral venous pressure in the dog is equivalent to 100—120 mm. water. (Method 4 α.)

3. The pressure in the superior longitudinal sinus with the flow of blood obstructed rises to double or more the normal cerebral venous pressure. (Method 4 β.)

4. The air index in the measuring apparatus exhibits perfectly the cardiac and respiratory undulations of the intra-cranial pressure. (Methods 2 and 3.)

5. The water manometer in connexion with the venous cavity in the occipital protuberance, or with the longitudinal sinus, exhibits the cardiac pulsations and large respiratory undulations. (Method 4 α and β.)

6. Salt solution (0·6 per cent.) can be slowly driven into the sub-dural space at the rate of about 1 c.c. a minute, without raising the intra-cranial pressure or producing any physiological effects. As much as 20 c.c. has thus been driven in during one experiment. (Method 1 *a.*)

7. Salt solution can be driven through from the parietal hole to a hole in the lumbar region of the spinal column. The whole of the subdural space can thus be syringed through.

8. Salt solution cannot be driven from a hole in the lumbar region out of a hole in the parietal region. The brain floats up and closes the parietal hole as a valve.

9. Salt solution, if driven in quickly with a higher pressure, produces a momentary rise of intra-cranial pressure and momentary physiological effects. These disappear very rapidly as the solution is absorbed.

10. On introducing 0·5 c.c. of salt solution within a bag in the sub-dural space of a cat (Method 1 *β*), no rise of intra-cranial pressure occurs, and no physiological effects are produced.

11. The introduction of more than 0·5 c.c. produces a lasting rise of intra-cranial pressure and physiological effects. These are: (1) slowing to stopping of respiration; (2) rise of blood pressure and slowing of the heart; (3) dilatation, or extreme constriction, of the pupil, and sometimes nystagmus.

12. The cat may become habituated to the smaller degrees of heightened intra-cranial pressure, and the physiological effects pass off.

13. Greater amounts than 1 c.c. cause an enormous and maintained rise of arterial pressure, with acceleration of the heart, inspiratory gasps at long intervals, followed by fall of arterial pressure and death.

14. 0·5 c.c. is the largest amount of displacement which can be perfectly compensated for in the cat, *i.e.*, this is the reduction of the cranial capacity which can be made up for by escape of cerebro-spinal fluid.

15. The brain of the cat of ordinary size, measured up to the level of the calamus scriptorius, equals in volume 26 c.c.

16. The amount of compensation is reduced to nothing on repeating the experiment a second time, and the effects which follow the introduction of the same quantity of salt solution into the bag are much more marked.

17. In the dog of the fox-terrier size the amount of compensation is 1·5 c.c.

18. The brain of the ordinary fox-terrier, on an average, equals 64 c.c. in volume.

19. The introduction of more than 1·5 c.c. in the dog produces

a lasting rise of intra-cranial pressure and physiological effects. These are the same as in the cat, except that there is no rise of blood pressure.

20. On cutting both vagi in the dog, the rise of blood pressure occurs as in the cat, and may reach enormous amounts.

21. The compensation is reduced to nothing in the dog on repeating the experiment a second time, and the effects are much more severe.

22. The physiological effects can be immediately removed by emptying the bag, and the pressure in the intra-cranial cavity recovers its old standard.

23. If the displacement caused by the bag is large, and maintained for a considerable time, there may be no relief and no expansion of the brain on emptying the bag.

24. Trephine holes made in various parts of the cranium and vertebral column afford no relief to the effects produced by the bag.

25. No fluid is to be found within the subdural space after the "bag experiment." The surface of the brain and the cavity of the skull are quite dry.

26. After the "bag experiment," salt solution (Method 1) can no longer be absorbed, and can no longer be driven through to a hole in the lumbar region, but acts in the same way and produces the same effects as the bag.

27. Marked physiological effects occur in the cat when the intra-cranial pressure is raised 10 mm. Hg above the normal. The measurement is taken over the medulla oblongata.

28. The venous pressure in the cavity of the occipital protuberance falls to zero when the "bag" is distended over the parietal region, *i.e.*, the entrance of blood is obstructed; the exit by the bony transverse sinuses remains open. (Method 4 *a.*)

29. The venous pressure in the superior longitudinal sinus rises when the "bag" is distended, *i.e.*, the exit is obstructed by the cannula, and blood is forced out of the tributary veins into the sinus. (Method 4 *β.*)

30. The normal venous pressure in each case at once returns when the bag is emptied.

Conclusion. November 18, 1893.

The capacity of the intra-cranial cavity can be diminished by the introduction of a foreign body into the subdural space. The first effect of the diminution is to expel the cerebro-spinal fluid. After its disappearance, further diminution of the space can only take place by equal diminution of the volume of the intra-cranial blood vessels, particularly of the veins and capillaries. *The restriction or arrest of the cerebral circulation thus produced is the efficient cause of the physio-*

logical disturbance observed after diminution of the intra-cranial cavity.

· In the animals experimented on, any considerable increase of the intra-cranial pressure above the normal (about 10 mm. mercury) interferes with or arrests the cerebral circulation.

A further Result.   November 27, 1893.

On driving salt solution coloured with methyl blue into the sub-dural space at the rate of 1 c.c. a minute, the urine which was collected from one ureter became of a blue colour in from 15 to 30 minutes.   On *post-mortem* examination, the upper portion of the first lymph gland in the cervical chain was found to be coloured blue; in the central nervous system the blue colour was found limited to the cerebral hemisphere on the side of injection, the base of the brain, and the cervical region of the cord.   Conclusion—The blood vessels form the pathway of absorption of fluid from the subdural space.

II. " Experimental Researches into the Functions of the Cerebellum."   By J. S. RISIEN RUSSELL, M.D., M.R.C.P., Assistant Physician to the Metropolitan Hospital.   Communicated by Professor VICTOR HORSLEY, F.R.S.   Received December 14, 1893.

(From the Pathological Laboratory of University College, London.)

(Abstract.)

The views that have been expressed as to the probable functions of the cerebellum are briefly alluded to, and the results obtained by previous investigators, as the direct outcome of experimentation, are detailed at greater length.

The objects of the present research were to determine :

1. Whether each lateral half of the cerebellum is capable of acting independently, or whether it is necessary for the connexions between the two halves to be intact, in order that the functions of the organ should be properly performed.

2. If impulses pass from one side of the organ to the other before they are transmitted to the cerebrum or spinal cord.

· 3. What is the nature of the impairment of movement which results when portions of the organ are removed.

. 4. What relationship exists between one half of the cerebellum

and the cerebral hemisphere of the opposite side, and what is its probable nature.

5. Whether one lateral half of the cerebellum is related mainly to the same side of the spinal cord, to the opposite side, or to both, and what the nature of the relationship is.

6. What symptoms resulting from experimental lesions of the cerebellum are mostly to be relied on for localisation.

7. Whether any, and if so which, of the symptoms are dependent on interference with the labyrinth or 8th nerve when experimental lesions of the cerebellum are produced.

The procedures adopted in attempting to elucidate these problems were :

1. Median vertical section separating the two lateral halves of the cerebellum from each other.

2. Extirpation of one lateral lobe.

3. Removal of half the organ, *i.e.*, of one lateral lobe together with one lateral half of the middle lobe.

4. One or other of the last two methods of procedure as a preliminary, and subsequent comparative investigation of the excitability of the two cerebral hemispheres.

5. Similar preliminary methods as in the last instance, followed by the administration of the essential oil of absinthe, and comparison of the effect of the resulting convulsions on the muscles of the two sides of the body.

6. Removal of both lateral lobes of the cerebellum.

7. Extirpation of the whole or half of the posterior part of the middle lobe.

8. Ablation of the whole organ.

9. Control experiments on the labyrinth and 8th nerve, which consisted in :

(*a*) Extirpation of the labyrinth.
(*b*) Intracranial section of the auditory nerve.
(*c*) Chemical irritation of the auditory nerve.

The results detailed refer chiefly to dogs, but the effects of similar lesions of the cerebellum in monkeys are contrasted with these. The question as to whether the cerebellum exerts any trophic influence is separately considered, as is a case of defective development of the cerebellum in a cat.

The investigation of the excitability of the two cerebral hemispheres, as tested by the induced current, yielded results of more than ordinary interest, for, whereas the excitability was equal on the two sides when the cerebellum was intact, the opposite hemisphere was the most excitable after unilateral ablation of the cerebellum, which difference in the excitability persisted, and was still present

even three months after the half of the cerebellum had been removed. The results obtained when absinthe was administered to animals which had been deprived of half the cerebellum also yielded highly interesting and instructive results. The increased excitability of the opposite hemisphere was evidenced by the exaggeration of the convulsions on the side of the cerebellar lesion; and it became also evident that the convulsions on the opposite side were diminished. Further, the curves obtained from the extensor muscles of the anterior extremity on the side of the cerebellar lesion showed that there was a marked alteration in the second stage of the convulsive seizure, for the tonus characteristic of this stage of similar convulsions evoked in dogs whose central nervous system was intact was either replaced by clonic spasms, or a large element of clonus was superimposed on the tonus. The curves from the muscles of both anterior extremities showed this alteration in the second stage of the convulsions when the whole instead of the half of the cerebellum had been previously removed.

The chief conclusions which appear to be warranted are that the one half of the cerebellum does not, in any great measure, depend on the cooperation of the other half for the proper performance of its functions. The bulk of the impulses pass from one half of the organ to the cerebrum, or spinal cord, without passing to the other half. Three factors are responsible for the defective movements which result on ablation of different parts of the organ—incoordination, rigidity, and motor paresis. The last of these is probably directly due to the withdrawal of the cerebellar influence from the muscles, while the exalted excitability of the opposite cortex cerebri, which results after unilateral ablation of the cerebellum, is probably a provision for compensation in this and other connexions. The one half of the cerebellum controls the cells of the cortex of the opposite cerebral hemisphere, and those of the anterior horns of the spinal cord on the same side chiefly, and on the opposite side to a slight extent. It is further suggested that either the cerebral hemisphere whose excitability is increased inhibits the opposite hemisphere, or that, under normal conditions, one half of the cerebellum inhibits the other half, which inhibition being no longer operative, owing to ablation of half of the organ, allows the remaining half to exert an increased control on the opposite cortex cerebri, or on the spinal centres of the same side, or possibly in both directions; but which is the most probable explanation of the phenomena observed is at present left an open question.

The symptoms characteristic of unilateral ablation of the cerebellum are :

1. Rotation and reeling to the opposite side.
2. The side of the face corresponding to the side of the lesion is

directed up, and the spinal column is arched with its concavity to the side of the lesion.

3. Incoordination, chiefly in the limbs of the same side.

4. Rigidity, most marked in the extremities of the side of the lesion, and preponderating in the anterior extremity of the side.

5. Exaggeration of the tendon reflexes most marked on the same side.

6. Motor paresis affecting both extremities on the side of the lesion, and the posterior extremity of the opposite side.

7. Anæsthesia and analgesia having the same distribution as the motor paresis.

8. Deviation of the opposite eyeball downwards and outwards, while that of the same side, if deviated, looks upwards and to the side of the lesion.

9. Lateral nystagmus, the jerks being from the opposite side towards the side of the lesion.

The phenomena which characterise ablation of different parts of the middle lobe, and of the whole organ, are similarly described. Incoordination is next discussed, and it is urged that, instead of looking on the cerebellum as a distinct organ which has a special function, distinct from those subserved by other parts of the central nervous system, it would be more correct to look on it as a part of that system, having many functions in common with other parts of it, the chief difference between one part of this great system and another being the degree in which different functions are represented in any given part: *e.g.*, with regard to motor power, the anterior extremity is maximally represented in the cerebrum and minimally in the cerebellum, whereas the trunk muscles are minimally represented in the cerebrum and maximally in the cerebellum. Arguments are adduced in favour of looking on the ocular deviations which result from ablation of parts of the cerebellum as paralytic rather than irritative phenomena, and two forms of nystagmus are recognised as consequent on cerebellar lesions, one which is spontaneous, and the other which is only evoked on voluntary movements of the globes, and the probable difference in their ætiology discussed. Finally, the phenomena characteristic of unilateral ablation of the cerebellum are contrasted with those the result of extirpation of the labyrinth, and it is shown that no single phenomenon is the same in the two.

III. "The Effect produced upon Respiration by Faradic Excitation of the Cerebrum in the Monkey, Dog, Cat, and Rabbit." By W. G. SPENCER, M.S., M.B., Assistant Surgeon to the Westminster Hospital. Communicated by Professor VICTOR HORSLEY, F.R.S. Received December 15, 1893.

(Abstract.)

The author of the paper brings forward evidence to show that, whilst the effect upon respiration of exciting the cerebrum in a non-anæsthetised animal is probably a complex one, yet, by careful regulation of the anæsthetic state, four constant effects can be obtained upon respiration by stimulation of the cortex, and these can be traced down each in a course of its own from the cortex to the mēdulla oblongata. In the production of the anæsthetic state the author lays stress not only upon the drug (ether) used, but also upon the following general conditions—apnœa, loss of blood, exposure of the brain, extravasation of blood, general exhaustion of the animal, and departure from health prior to the experiment.

The four effects upon respiration obtained in this research are as follows:—

A. *Diminution of Action.*

Slowing and Arrest of the Respiratory Rhythm.—The cortical area where this result was obtained is situated just outside the olfactory tract in front of the point where the tract joins the temporosphenoidal lobe. On exposing successive and vertical sectional surfaces of the hemisphere the same result was obtained by exciting in the line of the strand of fibres known as the olfactory limb of the anterior commissure. After decussating at the anterior commissure, the tract is continued backwards on either side of the infundibulum into the red nucleus below and external to the aqueduct at the plane of exit of the 3rd nerve.

B. *Increased Action.*

1. *Acceleration.*—Commencing from a point on the convex surface of the cortex within the "sensori-motor" area, the effect may be followed back just below the lenticular nucleus where it borders on the outer and ventral portion of the internal capsule; the strand runs

at first external and then ventral to the motor portion of the internal capsule, and so reaches the tegmentum. The lines from the two sides meet in the interpeduncular grey matter at the level of and just behind the exit of the 3rd nerve.

2. *Hyperinspiratory Clonus* ("snuffing movements").—This effect was obtained by excitation at the junction of the olfactory bulb and tract, and then carrying the stimulation backwards along the olfactory tract; the same result was found when the uncinate convolution of the temporo-sphenoidal lobe was irritated. Followed from the uncus this excitable region passed behind the optic tract to the crus, and then lay ventrally to the crusta. The excitable tract on each side thus converged towards the middle line at the upper border of the pons.

3. *Hyperinspiratory Tonus.*—This experimental result is of such frequency and constancy as to be clearly an important general phenomenon. It can be elicited in various ways : *e.g.*, excitation of the descending motor tract in the corona radiata and internal capsule yielded this result ; so did excitation of the 5th nerve and dura mater, as well as the sciatic nerve, both before and after complete removal of the cerebrum at the tentorium cerebelli.

The author finds medullated fibres in prepared microscopical vertical (frontal) sections of the brain running in the same course as that indicated by faradic excitation of the living surface of the section of the hemisphere. For his conclusions he has relied solely upon tracings of the respiratory movements. Fifty-six tracings are included as illustrations, together with thirty photographs of brains and brain sections to show the precise points excited. The author records his thanks to Mr. Horsley for help, and to Dr. Howard Tooth for the loan of excellently-prepared sections.

IV. " The Pathology of the Œdema which accompanies Passive Congestion." By WALTER S. LAZARUS-BARLOW, M.B., M.R.C.P. Communicated by Professor ROY, F.R.S. Received December 22, 1893.

(From the Pathological Laboratory, Cambridge.)

(Abstract.)

The author reviews the literature of the subject, and points out that the question of time has not been sufficiently considered by previous investigators.

He examines the view which, at present, is usually accepted, and which explains the œdema accompanying passive congestion upon purely mechanical principles.

He estimates the occurrence or non-occurrence of œdema by the specific gravity of the blood and blood-plasma, arterial and venous, of muscle and of skin, regarding these as more delicate tests of the presence or absence of œdema than the rougher methods of inspection, measurement, and pitting on pressure.

Having raised the pressure in the femoral vein to 50 mm. of mercury, he finds that there is no alteration in the specific gravity of the blood or blood-plasma of the muscle or of the skin, nor is there any increase in the amount of the lymph-flow, though such a pressure be maintained constant for an hour.

In the affected limb only is any change to be noted, and here there s a rise in the specific gravity of the venous blood and blood-plasma, which depends upon the longer sojourn of the blood in the limb and the consequent greater removal of the more watery portion from a given volume of blood.

Inasmuch as it is essential upon a purely mechanical explanation that the exudation from the blood-vessels should be increased in amount synchronously with the increase of pressure, and no such exudation is found to take place during an hour after the pressure in the veins has been raised, the author considers that the mechanical explanation is not supported by facts.

Since all forms of œdema are accompanied by an insufficient supply of blood to meet the requirements of the tissues, the author investigated the effect of different varieties of anæmia upon the occurrence of œdema. The varieties investigated were :—

1. Prolonged complete anæmia, lasting three hours.
2. Hæmostasis, or cutting-off of the limb, with whatever blood and lymph it may contain, from the rest of the circulation, by means of a tight ligature, for one hour.
3. Complete anæmia combined with stimulation of the sciatic nerve, and persistence, *in situ*, of the products of muscle-metabolism, the whole lasting one hour.

After each of these three varieties of anæmia the effects of active congestion, and of venous obstruction, were separately considered.

It was found that œdema occurs, as shown by a fall in the specific gravity of the muscle and skin, and a rise in the specific gravity of the blood, after all these conditions of anæmia, and the author concludes, therefore, that starvation of the tissues plays an important part in the occurrence of œdema.

The amount of œdema obtained, however, was found to be greater in those cases in which the limb had been subjected to the action of venous blood, and the longer the action of the venous blood was allowed to obtain, the greater the amount of œdema. The author concludes that the presence of the products of tissue metabolism at

the site of their formation plays a part in the occurrence of œdema even more important than that played by starvation. ·

The greatest amount of œdema was obtained with venous obstruction after anæmia and stimulation of the sciatic nerve.

The author shows that stimulation of the nerve of a muscle normally produces changes which lead to an absorption of water by the muscle, and he concludes that the œdema which accompanies passive congestion depends upon an excess of the normal process whereby the nutrition of the tissues and the removal of the waste products of their metabolism are carried out, the supply of lymph being excessive only because the demands of the tissues are excessive.

The part played by the blood-vessels the author regards as somewhat uncertain. Sharing in the general starvation of the limb, their function must be modified in some as yet unrecognised way; nevertheless, he considers that the part played by them is subordinate to the part played by the tissues outside the blood-vessels.

Presents, *January* 25, 1894.

Transactions.

Berlin :—Gesellschaft für Erdkunde. Zeitschrift. Bd. XXVIII. No. 5. 8vo. *Berlin* 1893. The Society.

Boston :—Colonial Society of Massachusetts. Bye-Laws, with Certificate of Incorporation and Lists of Officers and Members. 8vo. *Boston* 1893. The Society.

Brussels :—Académie Royale des Sciences. Annuaire. 1894. 8vo. *Bruxelles.* The Academy.

Cambridge, Mass. :—Museum of Comparative Zoology, Harvard College. Annual Report of the Curator. 1892–93. 8vo. *Cambridge* 1893. The Museum.

Halle :—K. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher. Nova Acta. Bände LVII—LVIII. 4to. *Halle* 1892–93; Leopoldina. Heft 28. 4to. *Halle* 1892 ; Katalog der Bibliothek. Lief. 4. 8vo. *Halle* 1893. The Academy.

London :—British Museum. Catalogue of Printed Books. Peasant— Penhydd, Periodico—Pentenyi. 4to. *London* 1893.
The Trustees.

Royal United Service Institution. Journal. Vol. XXXVIII. No. 191. 8vo. *London* 1894. The Institution.

Society of Biblical Archæology. Proceedings. Vol. XVI. Parts 1—2. 8vo. *London* 1893. The Society.

Naples :—Accademia delle Scienze Fisiche e Matematiche. Rendiconto. Serie 2. Vol. VII. Fasc. 8—12. 4to. *Napoli* 1893.
The Academy.

Transactions (*continued*).

Accademia Pontaniana. Atti. Vol. XXIII. 4to. *Napoli* 1893.
The Academy.

New York:—American Museum of Natural History. Bulletin. Vol. V. Pp. 337—352. 8vo. *New York* 1893.
The Museum.

Toronto:—Mathematical and Physical Society. Papers. 1891-92. 8vo. *Toronto* 1892. The University, Toronto.

Pathological Society. Proceedings and Transactions. Sessions 1889-91. Vols. I—II. 8vo. *Toronto.*
The University, Toronto.

Toulouse:—Faculté des Sciences. Annales. Tome VII. Fasc. 4. 4to. *Toulouse* 1893. The Faculty.

Vienna:—K.K. Geologische Reichsanstalt. Verhandlungen. 1893. Nos. 11—14. 8vo. *Wien.* The Institute.

Washington:—Bureau of Ethnology. Ninth Annual Report. 4to. *Washington* 1892 ; Bibliography of the Salishan Languages. 8vo. *Washington* 1893. The Bureau.

U.S. Department of Agriculture. Experiment Station Record. Vol. IV. No. 12. Vol. V. No. 2. 8vo. *Washington* 1893.
The Department.

Würzburg:—Physikalisch-Medicinische Gesellschaft. Sitzungs-berichte. Jahrg. 1893. Nos. 7—9. 8vo. *Würzburg.*
The Society.

Yokohama:—Asiatic Society of Japan. Transactions. Vol. XXI. 8vo. *Yokohama* 1893. The Society.

Observations and Reports.

Cambridge, Mass:—Astronomical Observatory of Harvard College. Annals. Vol. XXV. Vol. XXIX. Vol. XXXI. Part 2. Vol. XL. Part 2. 4to. *Cambridge* 1893. The Observatory.

India:—Tide Tables for the Indian Ports for the year 1894. Two parts. 8vo. *London.* India Office.

Leyden:—Sterrenwacht. Verslag van den Staat der Sterrenwacht. 1890-93. 8vo. *Leiden* 1892-93. The Observatory.

London:—Nautical Almanac Office. Nautical Almanac for 1897. 8vo. *London* [1893]. The Admiralty.

Washington:—Weather Bureau, U.S. Department of Agriculture. Monthly Weather Review. October, 1893. 4to. *Washington* 1893. The Bureau.

Abney (Capt. W. de W.), F.R.S. Chemical Action and Exposure; or, a Failure in a Photographic Law. 8vo. *London* 1893.
The Author.

Hertz (H.) Electric Waves; being Researches on the Propagation of Electric Action with Finite Velocity through Space. Authorised English Translation by D. E. Jones. 8vo. *London* 1893. Professor D. E. Jones.

Micheli (M.) Alphonse de Candolle et son Œuvre Scientifique. 8vo. *Genève* 1893. The Author.

Quatrefages de Bréau (J. L. A. de) Notice Biographique. 4to. [Private print.] Madame Quatrefages de Bréau.

Rodrigues (J. B.) Plantas Novas cultivadas no Jardim Botanico do Rio de Janeiro. No. 3. 4to. *Rio de Janeiro* 1893. The Author.

Map of England and Wales showing Lines of Equal Magnetic Declination for January 1, 1894. With a Reprint from the 'Colliery Guardian.' Two copies.
Mr. W. Ellis, F.R.S., and The Editor, 'Colliery Guardian.'

"On Copper Electrolysis *in Vacuo*." By WILLIAM GANNON, M.A., "1851 Exhibition" Scholar, Queen's College, Galway. Communicated by ARTHUR SCHUSTER, F.R.S. Received November 14,—Read December 7, 1893.

The following research upon the electrolysis of copper sulphate *in vacuo* was commenced nearly two years ago, at the suggestion of Dr. Schuster, and the experiments were made in the Physical Laboratory of the Owens College.

The electrolysis of copper salts is interesting, not only theoretically as affording a verification of Faraday's Law of Electrolytes, but also practically on account of its constant use in the graduation of current-measuring instruments, such as tangent galvanometers and ammeters. It is known that copper sulphate in solution does not conform rigorously to the simple form in which Faraday's law is generally expressed. Gray,[*] who made a detailed examination of the electrolysis of copper sulphate, found that the weight of the deposit is very variable in neutral solutions for the same current and the same interval of time; and he also showed that, in solutions containing a little free sulphuric acid, this inconstancy was removed, but that the weight was a function of the temperature of the solution and of the current density at the cathode. His results with acid solutions are graphically represented by curves (partly reproduced at the end of

[*] 'Phil. Mag.,' vols. 22 and 25 (1886–88).

this paper), an inspection of which shows that the deposit is heavier the higher the current density and the lower the temperature. ("Current density" is defined as the ratio of the value of the current in ampères to the total immersed surface of the cathode plate.) A very possible explanation of this anomaly is furnished by the work of Gore[*] and Gray,[†] who independently found that copper dissolves to a very appreciable, though variable, amount in solutions of copper sulphate.

The secondary chemical reactions which follow—chiefly the formation of basic salts—complicate the electrolysis. This corrosion of copper plates in the sulphate solution is much diminished if a little free sulphuric acid is present, with the result that the electrolysis of acid solutions yields more consistent results than are obtainable with nearly neutral solutions. Now, Schuster[‡] found that the loss in weight of copper plates in a solution of copper sulphate does not occur if the air be removed from the solution. It is therefore very probable that it is the oxygen of the air present in the solution that causes this chemical corrosion; and hence it was of interest to examine if any difference could be found between the weights of the deposits of two copper voltameters, one of which would be placed *in vacuo*. Schuster and Crossley[§] showed that the silver deposit is slightly greater *in vacuo* than in air; and the experiments tabulated in this paper point out, with certain limitations, a similar result.

The plan of these experiments was simple. The same current passed through two voltameters connected in series, one being under the ordinary atmospheric pressure and the other in a partial vacuum. The voltameters, in most of the experiments, consisted of ordinary glass beakers, containing the solutions of copper sulphate, into which dipped three parallel copper plates of the same size, the centre one acting as the cathode, and the side ones forming a double anode. The plates were held in position by means of German silver clips pressing against vertical brass supports which were attached to an ebonite framework. One voltameter was placed in an inverted bell-jar, into the neck (lower part) of which was fitted an india-rubber cork. Through the cork, which was coated with Faraday cement, passed three glass tubes, one connected with an exhaust pump and the remaining two containing the leads. In some of the experiments another tube was introduced, through which was passed into the jar a stream of nitrogen gas previous to exhaustion; but as this did not give any better results, it was discarded. At the bottom of the bell-jar inside was a support for the beaker, and on the latter rested

[*] 'Nature,' vol. 25, p. 473.
[†] 'Phil. Mag.,' vol. 22, p. 400, 1886.
[‡] See "Note" at end of this paper.
[§] 'Roy. Soc. Proc.,' vol. 50, pp. 344—358.

the framework with the three plates. In addition to the voltameter, the jar contained a small mercury gauge. The upper rim of the jar was ground, and previous to exhaustion was coated with grease, upon which pressed a ground-glass plate. The current was derived from storage cells, and was measured by a tangent galvanometer or a Thomson's magnetostatic centiampèremeter; it was adjusted to the proper value, and kept constant throughout an individual experiment by having in circuit a carbon rheostat and a set of specially prepared resistances of different values. The copper plates were made of commercial sheet copper (24 B.W.G.) : they were cleaned with emery paper, nitric acid, caustic potash, tap water, and, finally, distilled water, and a deposit was laid on them before being weighed for an actual experiment. The deposit was treated in the way recommended by Gray; I found it advantageous to have the distilled water hot, as on removing the plate the deposit dries more quickly, and consequently the possibility of oxidation occurring is diminished. The plates, after being in the balance case for a variable period— never less than three hours, generally over night—were weighed on a 16-in. Oertling balance, which weighed accurately to 1 tenth-milligram. The solutions were made by dissolving ordinary commercial sulphate in distilled water and filtering; the solutions with no free acid added were used immediately, so as to conduct the electrolysis before the formation of basic salts; the acid solutions contained 1 per cent. free sulphuric acid. When all the joints were air-tight, by being closed with cement, no difficulty was experienced in retaining the partial vacuum constant throughout each individual experiment. Leakage of the current at either voltameter was tested for throughout the experiments, and this point was considered satisfactory when, both voltameters being under atmospheric pressure, the deposits did not differ by more than 1 or 2 tenth-milligrams. Particular attention was paid to the handling of the plates before and after each experiment, especially in the replacing in, or removal from, their clips. By means of a small rod, acting as a lever, friction was prevented between the clips and plates, and hence the slight danger of loss of copper prevented. Immediately after the current was stopped in each experiment, the framework holding the plates was quickly removed from the solution and plunged into distilled water so as to remove all solution from the plates—oxidation occurs very rapidly if any solution remains on the plates, even for a very short time.

My first object was to ascertain if any difference in the weight of the deposit was caused by placing one voltameter *in vacuo*, without any special regard to the current density (which throughout all the experiments was the same at both cathodes). The experiments arranged in Table I show an appreciable, though inconstant, differ-

Table I

Date.	Density of solution.	Current in ampères.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.	Remarks.
						Vacuum.	Air.			
1892.										
Jan. 26........	1180	1·0	15°·0	40	0·62	0·8589	0·8579	0·0010	+ 11	
„ 28........	1168	1·0	22·0	49	0·75	0·9770	0·9652	0·0118	+135	
Feb. 8........	1168	1·0	18·9	40	0·62	0·8359	0·8342	0·0017	+ 20	
„ 9........	1178	1·0	17·5	41	0·62	0·8947	0·8915	0·0032	+ 36	
„ 18........	1177	1·0	15·0	40	0·62	0·8272	0·8282	0·0010	− 12	Deposits oxidised?
„ 19........	1171	1·0	16·8	40	0·62	0·8400	0·8370	0·0030	+ 35	
„ 20........	—	1·0	13·1	35	0·50	0·6768	0·6678	0·0090	+133	
Mar. 17........	1070	0·9	14·6	39	0·75	0·6849	0·6844	0·0005	+ 7	⎱ Some vacuum deposit lost.
„ 18........	1110	0·8	15·4	35	0·62	0·5600	0·5589	0·0011	+ 18	⎰
„ 22........	1095	0·7	18·0	45	0·62	0·6345	0·6310	0·0035	+ 55	

The solutions in each experiment contained no free acid, and were not previously used in any experiments.

ence. In ten experiments, with the sulphate solution containing no free acid, nine gave a greater deposit *in vacuo* than in air, one giving a negative difference. In this experiment (February 18) the deposit was not of the usual colour, and it is possible it was oxidised. Great care was necessary in washing the vacuum deposit, as often the copper was deposited in a loose form at and near the edges; in the experiments of March 17 and 18 a little of the vacuum deposit was lost in drying between the folds of blotting paper. It was not to be expected that the experiments in this table would show very concordant results; as, even presuming that the deposit *in vacuo* is constant, the inconstancy of deposits in air from neutral solutions would cause an inconstant difference.

In order to get a constant deposit in air, I next added acid to the air solutions and compared the deposits from these with the deposits from a neutral solution *in vacuo*. Table II includes experiments conducted in this way: in the experiments of February 24 and 29 some of the vacuum deposit adhered to the blotting paper and was lost. I cannot account for the negative result of February 25. The remaining experiments show fairly concordant differences. It will be observed from Tables I and II that, with the exception of those experiments in which some of the deposit was mechanically lost, the percentage difference is greater with acid solutions in air than with neutral solutions, which agrees with Gray's observations that the deposit (in air) in neutral solutions is generally higher than in acid solutions.

I have brought together the experiments included in Table III, although the results are very inconsistent and puzzling. It will be seen that, if the neutral solutions have been used in previous experiments and acid added to them for a fresh experiment, the difference between the weights of the two deposits varies not only in amount but also in sign. An explanation of this may be that electrolysing a neutral solution changes its chemical constitution, and that adding acid afterwards does not remove all basic salts. Accepting this possible explanation, I abandoned for the present using neutral sulphate in either voltameter. In all the remaining experiments described in this paper, both solutions were freshly prepared, not previously used in any experiment, and contained 1 per cent. free sulphuric acid. The results I have obtained in this way are more concordant and very interesting. A deposit obtained from a neutral solution *in vacuo* shows the same looseness in deposition as in air; but the addition of a little free acid causes the copper to be deposited in a compact form, which is not liable to be lost in the washing or drying.

Table II.

Date.	Density of solution.	Current in ampères.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.	Remarks.
						Vacuum.	Air.			
1892.										
Feb. 24	1110	1·0	18°·2	40	0·68	0·8122	0·8115	0·0007	+ 8	{ Some vacuum deposit lost.
,, 25	1091	1·0	14·6	49	0·69	1·0660	1·0684	0·0024	− 28	
,, 26	1122	1·0	16·3	45	0·62	0·9802	0·9773	0·0030	+ 29	
Mar. 24	1095	0·7	18·5	40	0·75	0·5768	0·5619	0·0149	+253	
,, 25	1095	0·7	17·1	39	0·62	0·5557	0·5320	0·0237	+445	{ Some vacuum deposit lost.
,, 28	1095	0·7	15·0	30	0·68	0·4852	0·4696	0·0156	+330	
,, 29	1093	0·6	14·5	47	0·62	0·5959	0·5868	0·0091	+151	
,, 29	1093	0·7	14·9	40	0·62	0·5719	0·5572	0·0147	+262	

Both solutions freshly prepared for each experiment; air solution with 1 per cent. free acid, vacuum solution neutral.

Table III.

Date.	Current in ampères.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.
					Vacuum.	Air.		
1892.								
Feb. 25	1·0	14·9	49	0·62	1·0181	1·0203	0·0022	− 20
,, 26	1·0	15·0	40	0·75	0·8575	0·8554	0·0021	+ 22
,, 29	1·0	17·0	49	0·62	1·1865	1·1859	0·0006	+ 5
Mar. 3	1·0	16·6	32	0·62	0·5878	0·5862	0·0016	+ 27
,, 18	0·75	?	40	0·75	0·5781	0·5726	0·0055	+ 95
,, 24	0·72	17·5	40	0·75	0·5429	0·5545	0·0116	−209
,, 25	0·77	17·6	42	0·87	0·5799	0·5930	0·0131	−220
,, 28	0·72	15·6	40	0·87	0·5705	0·5648	0·0057	+100
,, 29	0·68	15·3	39	0·75	0·5235	0·5234	0·0001	+ 2

The solutions were used previously without any free acid; 1 per cent. acid added in these experiments.

The following tables are not arranged in the order in which the experiments were made.

Table IV includes four experiments in which the current density was approximately 0·007 ampère per square centimetre of "active" cathode, or 1 ampère to 135 sq. cm. All the experiments gave the vacuum deposit higher than the air deposit, and the percentage differences agree fairly. The mean value = 0·16 per cent. at a mean temperature of 18°·1.

Table V includes three experiments in which the current density was 0·006 ampère per square centimetre. It will be seen the vacuum deposit is higher than the air deposit in the three experiments. Mean value of difference = 0·10 per cent. at a mean temperature of 16°·5.

Table VI includes four experiments at a current density of 0·005 ampère per square centimetre. Again the vacuum deposit is higher than the corresponding air deposit. Mean value of difference = 0·14 per cent. at a mean temperature of 17°·5.

Table VII includes five experiments at a current density of 0·004 ampère per square centimetre. All the vacuum deposits are higher than the corresponding air deposits. Mean value of the difference = 0·17 per cent. at a mean temperature of 19°.

Table VIII includes five experiments at a current density of 0·0033 ampère per square centimetre. Again deposit *in vacuo* is higher than the deposit in air. Mean value of difference = 0·14 per cent. at a mean temperature of 15°·5.

Table IX includes seven experiments at a current density of 0·0027 ampère per square centimetre. The same results obtained here as in the preceding tables; but the experiments of April 12 and 13 do not agree very well with the others. Mean value of difference = 0·16 per cent. at a mean temperature of 16°·6.

Table X includes nine experiments in which the strength of current was approximately 0·01 ampère per square centimetre. This table is very interesting, as showing that near this particular current density the previously observed differences cease to exist. The nine experiments never gave a greater difference between corresponding deposits than 1 tenth-milligram. The voltameters were carefully tested for leakage before and after these experiments; and the experiment of April 7 (Table IX), in which there was a percentage difference of 0·12, follows that of April 5, without any alteration in the arrangement of the apparatus. In addition, the experiments of December 2 and 3 were made with a different bell-jar and a different arrangement from that used in the previous experiments. It may be fairly concluded that at this density no difference in the deposit exists.

Table XI includes three experiments at a density of 0·02 ampère per square centimetre. It will be seen that there is practically no difference between the deposits.

Table IV.

Date.	Current in ampères.	Active area of cathodes in square centimetres.	Current density.	Density of solution.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.
								Vacuum.	Air.		
1893.											
Aug. 26	0·676	96·6		1123	17·7	66	0·75	0·8517	0·8512	0·0005	+6
,,　28	0·676	96·6	1 ampère to 135 sq. cm., or 0·007 ampère per sq. cm.	1123	18·2	69	0·75	0·8569	0·8562	0·0007	+9
,,　29	0·676	96·6		1123	18·9	69	0·75	0·8541	0·8547	0·0006	+7
,,　30	0·676	96·6		1123	17·5	72	0·75	0·8619	0·8625	0·0006	+7
					Mean temp. } 18·1					Mean diff. }	+7

The solutions were freshly prepared in each experiment, and contained 1 per cent. free acid.

Table V.

Date.	Current in ampères.	Active area of cathodes in square centimetres.	Current density.	Density of solution.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.
								Vacuum.	Air.		
1892. July 20	0·43	72		1142	17°·8	91	0·75	0·7618	0·7612	0·0006	+ 7
,, 22	0·43	72	1 ampère to 166 sq. cm., or 0·006 ampère to each sq. cm.	1142	15·6	98	0·75	0·7663	0·7654	0·0009	+12
,, 25	0·43	72		1151	16·2	85	0·75	0·7217	0·7210	0·0007	+10
				Mean temp. } 16·5						Mean diff. }	+10

The solutions were freshly prepared in each experiment, and contained 1 per cent. free acid.

Table VI.

Date.	Current in ampères.	Active area of cathodes in square centimetres.	Current density.	Density of solution.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.
								Vacuum.	Air.		
1898. Aug. 8	0·41	82		1141	17°·6	105	0·75	0·8338	0·8329	0·0009	+12
,, 9	0·41	82	1 ampère to each 200 sq. cm. or 0·005 ampère per sq. cm.	1141	17·2	112	0·62	0·8413	0·8400	0·0013	+16
,, 10	0·41	82		1141	17·8	104	0·62	0·8323	0·8312	0·0011	+13
,, 11	0·41	82		1141	17·4	109	0·75	0·8407	0·8396	0·0011	+14
					Mean temp. } 17·5						Mean diff. } +14

The solutions were freshly prepared in each experiment, and contained 1 per cent. free acid.

Table VII.

Date.	Current in ampères.	Active area of cathodes in square centimetres.	Current density.	Density of solution.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.
								Vacuum.	Air.		
1883. Aug. 21	0·386	96·6		1182	18°·4	126	0·62	0·8966	0·8950	0·0016	+18
,, 22	0·386	96·6	1 ampère to 250 sq. cm. or 0·004 ampère per sq. cm.	1113	20·0	115	0·75	0·8149	0·8136	0·0013	+17
,, 23	0·386	96·6		1145	19·6	120	0·75	0·8665	0·8652	0·0013	+16
,, 24	0·386	96·6		1145	18·2	120	0·75	0·8754	0·8739	0·0015	+18
,, 25	0·290	72·0		1102	18·7	125	0·75	0·7996	0·7984	0·0012	+15
					Mean temp. } 19·0					Mean diff. } +17	

The solutions were freshly prepared in each experiment, and contained 1 per cent. free acid.

Table VIII.

Date.	Current in ampères.	Active area of cathodes in square centimetres.	Current density.	Density of solution.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.
								Vacuum.	Air.		
1892.											
Apr. 29	0·24	74·0		1132	15·0	170	0·75	0·8225	0·8214	0·0011	+14
May 3	0·24	74·0	1 ampère to 300 sq. cm., or 0·0083 ampère per sq. cm.	1113	14·5	162	0·75	0·8199	0·8186	0·0013	+16
„ 4	0·24	74·0		1113	16·7	161	0·75	0·8206	0·8194	0·0012	+15
„ 5	0·24	74·0		1113	14·9	161	0·75	0·8213	0·8201	0·0012	+15
July 18	0·24	72·0	..	1145	16·5	160	0·75	0·8222	0·8213	0·0009	+12
				Mean temp. } 15·5						Mean diff. }	+14

The solutions were freshly prepared in each experiment, and contained 1 per cent. free acid.

Table IX.

Date.	Current in ampères.	Active area of cathodes in square centimetres.	Current density.	Density of solution.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.
								Vacuum.	Air.		
1892.											
Apr. 7	0·2	74		1032	18·0	162	0·75	0·6406	0·6398	0·0008	+12
,, 9	0·2	74		1032	15·3	147	0·68	0·5752	0·5744	0·0008	+14
,, 11	0·2	74	1 ampère to 370 sq. cm., or 0·0027 ampère per sq. cm.	1035	17·2	162	0·75	0·5674	0·5667	0·0007	+12
,, 12	0·2	74		1035	16·0	154	0·75	0·5944	0·5929	0·0015	+25
,, 13	0·2	74		1035	15·5	185	0·75	0·7104	0·7088	0·0016	+22
July 22	0·2	74		1124	17·4	180	0·75	0·6851	0·6842	0·0009	+13
,, 24	0·2	74		1124	16·9	180	0·75	0·6736	0·6725	0·0011	+16
				Mean temp. } 16·6						Mean diff. } +16	

The solutions were freshly prepared in each experiment, and contained 1 per cent. free acid.

Table X.

Date.	Current in ampères.	Active area of cathodes in square centimetres.	Current density (approx.).	Density of solution.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.
								Vacuum.	Air.		
1892.											
Apr. 1	0·79	80		1130	15·7°	41	0·62	0·6378	0·6378	0·0000	±0·00
,, 1	0·80	80		1130	15·7	40	0·62	0·6279	0·6280	0·0001	−0·01
,, 2	0·78	80		1130	15·9	40	0·75	0·6272	0·6271	0·0001	+0·01
,, 2	0·79	80	1 ampère to 100 sq. cm., or 0·1 ampère per sq. cm.	1130	16·0	42	0·75	0·6367	0·6368	0·0001	−0·01
,, 4	0·78	79		1115	16·5	40	0·62	0·6085	0·6084	0·0001	+0·01
,, 4	0·79	79		1120	18·3	40	0·62	0·6148	0·6149	0·0001	−0·01
,, 5	0·79	79		1120	17·0	45	0·62	0·6971	0·6971	0·0000	±0·00
Dec. 2	0·84	84		1067	11·0	47	0·75	0·7307	0·7306	0·0001	+0·01
,, 3	0·84	84		1087	12·0	40	0·75	0·6186	0·6186	0·0000	±0·00
										Mean diff	} ±0·00

The solutions were freshly prepared in each experiment, and contained 1 per cent. free acid.

Table XI.

Date.	Current in ampères.	Active area of cathodes in square centimetres.	Current density.	Density of solution.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.
								Vacuum.	Air.		
1893.											
Jan. 12	1·45	76·9	1 ampère to 53 sq. cm., or 0·019 ampère per sq. cm.	1180	15°·0	25	0·50	0·8762	0·8762	0·0000	±0·00
,, 13	1·45	76·9		1180	16·3	28	0·50	0·9046	0·9046	0·0000	±0·00
,, 14	1·45	76·9		1180	16·0	27	0·62	0·8943	0·8942	0·0001	−0·01
									Mean diff.		−0·01

The solutions were freshly prepared in each experiment, and contained 1 per cent. free acid.

Table XII.

Date.	Current in ampères.	Active area of cathodes in square centimetres.	Current density.	Density of solution.	Temp. of room.	Time in minutes (approx.).	Vacuum in inches of mercury.	Deposit.		Difference.	Difference in 10,000 parts.
								Vacuum.	Air.		
1893.											
Sept. 13	1·25	96·6	1 ampère to 75 sq. cm., or 0·013 ampère per sq. cm.	1180	16°·2	30	0·62	0·8222	0·8222	0·0000	±0·00
,, 14	1·25	96·6		1180	17·4	30	0·75	0·8297	0·8296	0·0001	+0·01
,, 15	1·25	96·6		1180	17·6	30	0·75	0·8314	0·8314	0·0000	±0·00
									Mean diff.		+0·01

The solutions were freshly prepared in each experiment, and contained 1 per cent. free acid.

Table XII includes three experiments at a density of 0·013 ampère per square centimetre. The deposits show no difference in weight.

It would thus appear that, at current densities above 0·01 ampère per square centimetre, there is practically no difference in weight of the deposits obtained from solutions of copper sulphate (made acid), one of which is under ordinary atmospheric pressure, and the other under reduced pressure; but at densities below this there is a very appreciable difference, the deposit in a partial vacuum being *always* greater than the corresponding deposit in air. *No experiment with acid solutions ever gave the vacuum deposit less than the air deposit.* Why this difference should exist at certain densities and not at others is not very clear. The chemical corrosion above referred to will be more marked in the air solutions at weak current densities, where the duration of the experiments is three to four hours, but it would not be expected that it would be altogether missing at densities where the duration of the experiments is less than forty minutes and less.

My experiments do not completely reveal the cause of the relations existing between the deposit and current density. They clearly show, however, that the oxygen present in the solution has a certain diminutive action on the weight of the deposit, and that this action is prevented (partly or wholly) by conducting the electrolysis *in vacuo*. The removal of the oxygen of the solution prevents the copper plates, and more particularly the copper deposit, from dissolving in the solution; but it does not prevent (apparently) what some physicists speak of as an electrical corrosion, which occurs only when the current is passing through the solution.

It is of interest to draw a curve representing the deposits obtained *in vacuo* with different current densities. This I have done by

means of the data in Table XIII. In this table I have collected the chief results of my experiments. By means of Gray's values I have reduced the observed differences to a temperature of 15° C., and then calculated the values *in vacuo*. The curve thus obtained is more uniform in its course than the curves for air.

Table XIII.—Summary of Experiments with fresh Acid Solutions. (Tables IV—XII.)

Table.	Current density.		Mean temp. of experiments.	Difference in 10,000 parts.	Difference reduced to 15° C.	Gray's proportionate values (in air) at 15°.	Proportionate values *in vacuo*.
	Ampères per square centimetre.	Square centimetres per ampère.					
XI	0·019	53	..	± 0	± 0·0	9997	9997
XII	0·013	75	..	± 0	± 0·0	9992	9992
X	0·010	100	..	± 0	± 0·0	9986	9986
IV	0·007	135	18°·1	+ 7	+ 5·5	9979	9984
V	0·006	166	16·5	+10	+ 9·0	9974	9983
VI	0·005	200	17·5	+14	+11·0	9971	9982
VII	0·004	250	19·0	+17	+13·0	9967	9980
VIII	0·0033	300	15·5	+14	+13·0	9964	9977
IX	0·0027	370	16·6	+16	+13·0	9961	9974

The results of my experiments may be briefly summarised :—

1. With two copper voltameters containing freshly made neutral solution of copper sulphate, one of which is under reduced pressure, the copper deposit in the partial vacuum is higher (for the same current, current density, and temperature) than the deposit under the atmospheric pressure; but the percentage difference is not constant.

2. If a little free sulphuric acid be added to the air solution, the percentage difference is more constant and higher than in 1.

3. The addition of acid to both voltameters causes the percentage difference to be constant within experimental errors. The experiments conducted under this condition show that—

i. For current densities above 0·01 ampère per square centimetre of active cathode, there is no practical difference between the two deposits.

ii. For current densities below 0·01 ampère per square centimetre, the vacuum deposit is very appreciably higher than the air deposit.

iii. A curve drawn representing the deposits obtained *in vacuo* at different current densities is more regular than the air curves, and for densities below 0·01 ampère per square centimetre is approximately a straight line.

"Note on the Action of Copper Sulphate and Sulphuric Acid on Metallic Copper." By ARTHUR SCHUSTER, F.R.S. Received November 14,—Read December 7, 1893.

Mr. Gannon in the foregoing paper refers to some unpublished experiments made by me a few years ago. These experiments were conducted for the purpose of satisfying myself that, as seemed *a priori* probable, the diminution of weight observed when metallic copper is exposed to the action of sulphuric acid or sulphate of copper is due to the presence of free oxygen in the liquid. Copper gauze was taken in order to deal with as large a surface as possible, and rolled up so as to fit into a piece of glass tubing. After the copper had been carefully washed, dried, and ignited in hydrogen, it was immersed in dilute sulphuric acid, the air above the acid was removed as far as possible, and the tube containing the gauze was then sealed hermetically. At the end of a fortnight a few tubes prepared in this way were opened and weighed after being subjected to exactly the same treatment as previous to immersion, that is to say, the copper was washed, dried, and ignited in hydrogen. The diminution in weight observed under these circumstances was insignificant. I cannot, unfortunately, now find the record of the actual weighings, but the quantities involved were about the same as in the next set of experiments. On January 26, 1891, four spirals of copper gauze were placed in a solution containing 20 per cent. of cupric sulphate, 5 or 10 per cent. by weight of sulphuric acid being added to the aqueous solution. The conditions thus approximated to the solutions which are used in the electrolysis of copper. The tubes were exhausted and sealed up: two of them were opened on February 2, and the two remaining ones on February 9; the weighings were taken after drying and ignition in hydrogen. The results are shown in the accompanying table:—

Time of immersion.	Amount of sulphuric acid.	Weight before immersion.	Weight after immersion.
7 days	10 per cent.	17·512	17·510
7 „	5 „	14·357	14·356
14 „	10 „	14·267	14·265
14 „	5 „	18·471	18·468

It will be seen that the diminution in weight is quite insignificant compared to what takes place in the presence of air, and may be due to some remnant of oxygen left. The late Mr. Hoskyns Abrahall, however, suggested that it might also be due to the formation of copper sulphide; and this suggestion was supported by the fact that traces of sulphuretted hydrogen were given up when the copper, after

immersion, was heated in hydrogen. The action would be represented by the formula

$$4Cu + SO_3 = CuS + 3CuO.$$

The above experiments prove that nearly the whole effect which is observed when copper is immersed in a solution of sulphate of copper or sulphuric acid is due to the presence of oxygen in the solution.

February 1, 1894.

Sir JOHN EVANS, K.C.B., D.C.L., LL.D., Vice-President and Treasurer, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

I. "Insect Sight and the Defining Power of Composite Eyes." By A. MALLOCK. Communicated by LORD RAYLEIGH, Sec. R.S. Received November 28, 1893.

The optical arrangement of the simple eyes of Vertebrates is well understood, but as regards the action of the composite eyes of Insects and Crustacea less certainty has hitherto prevailed.

In the former class of eye a single lens, or its equivalent, forms an image on a concave retina, built up, as a sort of tesselated pavement, of the sensitive terminations of the fibres of the optic nerve, and, if the lens is perfect and the pupil large enough, the definition is limited by the distance apart of the nerve-terminations, for, in order that two objects may appear as two to the eye, they must subtend at least such an angle that their images as formed by the lens shall not fall on the same nerve-termination.

In the human eye the distance between the sensitive points on the retina is such that it subtends about a minute of arc at the optic centre of the lens, and in good eyes the optical part of the apparatus is sufficiently perfect to allow of this degree of definition being attained over a small part of the field of view.

For reasons, however, which will be given presently, such definition as this is not to be looked for in composite eyes.

The general plan on which all composite eyes are constructed is that of a convex retina having a separate small lens in front of each sensitive part, together with an arrangement of screens which allows

only that light coming from the immediate neighbourhood of the axis of the lens to reach the nerve.

The theory of "mosaic vision" put forward by Johannes Müller has been opposed by some physiologists, who appear to have considered that each lens of a composite eye formed a complete image which was taken cognizance of by the nerves as in the vertebrate eye, and that the whole of these images were in some way added together and arranged by the brain; I here bring forward some optical reasons which show that Müller's view is the true one.

On the supposition, therefore, of "one lens, one impression," the definition obtained by a composite eye will be measured by the total solid angle of view ÷ whole number of lenses in the eye.

The simplest form of composite eye would be a spherical shell, AB, fig. 1, perforated with radial holes, *c, c, c*, the diameter of these

FIG. 1.

holes being small compared with the thickness of the shell.

If sensitive paper were placed in contact with the inner surface of the shell, it would be impressed with a picture of surrounding objects, for the light which reaches the bottom of any hole is limited to that making an angle less than ½DEF with the axis of the hole, which angle is of course equal to the diameter of the hole ÷ half its length.

It is interesting to see what proportions would have to be given to an eye of this kind if the definition is to be as good as that of the human eye.

The limit of definition in this case being 1 min., the holes would have to be 7000 diameters long (since 1 min. is nearly 1/3500) and in order that diffraction may not interfere materially with the result,[*] the

---

[*] It may be shown that the hole should not be much smaller than the first Huyghens zone of a system for which, if $\lambda/r = r/R$, R = the length of the hole, λ and r being the wave-length of light and the radius of the zone respectively. How

diameter of the holes should not be less then 2000 wave-lengths of light, say $\frac{1}{35}$ in. Hence the thickness of the shell will be 7000 × $\frac{1}{35}$ in., or 23 ft.

The radius of the sphere may be determined by the condition that, if the picture is to be continuous, the adjacent holes must just be in contact at the internal surface of the shell, that is to say the diameter of the hole, viz.: $\frac{1}{35}$ in., must subtend 1 min. at the internal radius of the shell, which makes this radius, therefore, 11 ft. 6 in.

Thus an eye of this construction and power of definition would consist of some part of a spherical shell of 34 ft. 6 ins. external radius, and 23 ft. thick, perforated with radial holes $\frac{1}{35}$ in. in diameter, and with their centres about $\frac{1}{8}$ apart on the external surface.

If still keeping 1 min. as the limit of definition, we substitute the arrangement actually found in composite eyes, and in place of the long tunnels in thick shell, we use short tunnels with a lens at the outer end of each tunnel, and a diaphragm at the inner end, pierced with a small central hole (fig. 2), the proportion of the eye will be

Fig. 2.

determined in the first place by the diameter of the lens which will just define 1 min., and secondly by making that diameter subtend 1 min. at the centre of the sphere.

Now the size of the image of a point formed by a lens (as seen from the optic centre of the lens) is inversely as the diameter of the lens, and it takes a lens 4 ins. in diameter to define 1 second, *i.e.*, to separate points 1″ apart; hence the lens which will just define 1 min. is $\frac{4}{60}$ or 0·066 in. in diameter.

The radius at which 0·066 in. subtends 1 min. is about 19 ft.

It is evident, therefore, that no composite eye of practicable dimensions, acting as supposed above, could be made to give definition even approaching that of the human eye.

much less than r the diameter of the hole may be is, to some extent, a matter of judgment depending on the degree to which it is considered desirable to reduce the intensity of the diffracted light.

If the diameter of the lenses is reduced, not only is the size of the sphere on which a given number of them would lie reduced, but, since the definition of each lens decreases with the diameter, a less number of lenses will be required to give the maximum definition attainable under the changed circumstances. Thus the radius of the sphere proper for the surface of a composite eye decreases as the square of the defining power of the separate lenses of which it is composed.

Let A and B (fig. 2) be two adjacent lenses, C and D the sensitive spots of the retina. Let θ be the angle between the axes of A and B, and χ the limit of definition of the lens. Then, if $\chi = \theta$, the image of a distant object in the axis of A will just fall clear of the sensitive point D, but, if $\chi > \theta$, both C and D will be illuminated by light from the same object.

Supposing, however, χ is less than θ, nothing will be gained in definition unless each lens has more than one sensitive point to operate on. If, then, we find that in actual composite eyes χ and θ are nearly equal, that is, that the difference in the direction in which the adjacent lenses point is nearly equal to the defining power of the lens itself, it becomes almost certain that each lens has only one sensitive point behind it.

The following table contains measures, recently made by me, of the diameters and angles between the axes of the lenses of various insect eyes, and, although the measure of the angle of view was necessarily rather rough, the agreement of the results, in the larger number of cases, with the supposition above made seems to me sufficiently remarkable.

In estimating θ there were two difficulties, one of which was that in many eyes the curvature of the surface was sharp at the margin and that the definition was probably bad there, and another that the line of sight of each lens was not always normal to the outer surface of the eye (fig. 3). Generally, I took the angle between the tangents

Fig. 3.

to the surface at the ends of a measured chord, choosing the chord so that the surface outside it should have fairly uniform curvature. The length of the chord was usually about three-quarters, or a little more, of that of the eye.

Taking the length of the chord as l, and r as radius of the sphere which best represents the surface of the eye, we have for the angle of view Θ,

$$\sin\tfrac{1}{2}\Theta = l/2r,$$

Species.	Length of body.	Greatest dimension of eye.	Diameter of aperture of ommatidium.	Angle between axes of adjacent ommatidia in minutes.	Defining power of lens of diameter d in minutes.
			d.	θ	χ
Diptera—					
1. Fly like a Bee, *Eristalis*	0·60	0·108	0·0012	56	55
2. Fly like a Wasp, *Sericomyia*	0·70	0·12	0·0016	48	71
3. Blow-fly, *Lucilia*	0·34	0·07	0·0018	84	35
4. Very small Flies, species not identified	0·20	0·026	0·00076	126	87
5. Ditto	0·13	0·021	0·0005	105	113
Hymenoptera—					
6. Hornet	1·0	0·152	0·0014	53	48
7. Wasp	0·7	0·088	0·0011	84	60
8. Bee	0·6	0·100	0·00072	50	90
9. *Chrysis*, scarlet and blue	0·4	0·045	0·00094	105	70
Lepidoptera—					
10. Small Cabbage White	0·8	0·059	0·00072	86	90
11. Red Admiral	1·0	0·072	0·00095	76	69
12. Small Copper	0·5	0·050	0·00071	100	93
13. Yellow under wing	0·75	0·064	0·00092	70	72
14. *Noctua*	0·7	0·060	0·00090	70	74
Dragon-flies—					
15. Large Dragon-fly, *Æschna cyanea*	3·5	0·282	Large lenses 0·0023 Small lenses 0·0016	48	41
16. *Libellula striolata*	2·5	0·191	Large lenses 0·0027 Small lenses 0·0015	50	45
17. Green Grass-hopper	1·1	0·057	0·0011	80	60
18. *Tipula*	1·0	0·027	0·00095	200	70

and $\theta = d/r$, where d is the diameter of the lens;

hence $$\theta = d/b \cdot 2\sin\tfrac{1}{2}\Theta.$$

The other columns of the table explain themselves.

On the whole, I think it must be concluded that Insects do not see well, at any rate as regards their power of defining distant objects, and their behaviour certainly favours this view; but they have an advantage over simple-eyed animals in the fact that there is hardly any practical limit to the nearness of the objects they can examine. With the composite eye, indeed, the closer the object the better the sight, for the greater will be the number of lenses employed to produce the impression; whereas in the simple eye the focal length of the lens limits the distance at which a distinct view can be obtained.

The best of the eyes mentioned in the table would give a picture about as good as if executed in rather coarse wool-work and viewed at a distance of a foot; and, although a distant landscape could only be indifferently represented on such a coarse-grained structure, it would do very well for things near enough to occupy a considerable part of the field of view.

II. "The Action of Heat upon Ethylene." By VIVIAN B. LEWES. Professor of Chemistry in the Royal Naval College, Greenwich. Communicated by Professor THORPE, F.R.S. Received December 6, 1893.

The decompositions of the simpler forms of hydrocarbons at an elevated temperature have always been recognised as a question of the greatest importance, as upon them is dependent a true conception of many of the actions taking place in the manufacture of coal gas and other kindred processes of destructive distillation.

Ethylene has in most cases been chosen as the hydrocarbon which would lend itself most readily to experimental researches upon this point, as, besides being one of the simplest, it is easily prepared, and is moreover found as one of the products in nearly all cases where organic compounds are subjected to distillation at high temperatures.

No sooner had the difference between ethylene and methane been recognised, than experiments were made by Deimann, Van Troostwyk, Lauwerenburg, and Bondt* to ascertain the action of heat upon the newly-formed compound, and the conclusions which they came to were that on heating no contraction in volume was observed, but that the tubes in which the decomposition was effected became coated with a black deposit, and drops of an oily body were formed, the gas

* 'Annales de Chimie et de Physique,' 1st series, vol. 21, p. 48.

at the same time losing its property of forming an oily liquid with chlorine.

These experiments were afterwards repeated by Fourcroy, Hecht, and Vauquelin,[*] who showed that when heated, ethylene yields hydrogen with deposition of carbon, whilst in 1805 William Henry[†] showed that ethylene was formed during the destructive distillation of organic bodies, and that on further heating the gas, other changes were observed, and the gas was eventually converted into carbon and hydrogen. The deposition of carbon was also noticed later by Quet,[‡] who on passing sparks through ethylene found that carbon was deposited, and formed a bridge between the poles used for the discharge, whilst Dalton showed by the continuous action of the electric spark that ethylene yielded double its own volume of hydrogen, carbon being deposited.

Marchand[§] came to the conclusion that at a red heat this gas splits up into methane and carbon, but at a white heat into carbon and nearly pure hydrogen, whilst Magnus, in 1847, made the important observation that on leading ethylene through a red-hot tube a contraction in volume followed ; the residual gas consisted of methane, hydrogen, and unchanged ethylene, whilst carbon was deposited, and fluid and even solid hydrocarbons were obtained.

In 1860 H. Buff and A. W. Hofmann[||] published a paper on the "Dissociation of Gaseous Compounds on Heating by Electricity."

They found that when a platinum spiral is heated by the galvanic current in pure ethylene there is at once a visible separation of carbon, which covers the sides of the tubes with a black deposit, whilst hardly any expansion in the volume of the gas takes place, from which they assume that the ethylene has split up into methane and carbon.

If the action on the gas, due to the incandescent platinum wire, is allowed to continue, then an increased amount of the gas undergoes dissociation, and soon after the separation of carbon commenced, they observed an expansion which is rapid at first, and in ten minutes reaches a maximum. Similar phenomena were noticed with the spark current ; at first the spark had a pale reddish tint which gradually turned to violet, immediate separation of carbon taking place, the spark being frequently stopped by scales of carbon which formed a bridge between the poles. They found that under these conditions the volume of gas expands very rapidly at first but afterwards more slowly, and that after twenty to twenty-five minutes, the point of maxi-

---

[*] Gilbert's 'Annalen,' vol. 2, p. 210.
[†] 'Nicholson's Journal,' 1805.
[‡] 'Comptes Rendus,' vol. 42, p. 903.
[§] 'J. für prakt. Chem.,' vol. 26, p. 478.
[||] Liebig's 'Annalen der Chemie,' vol. 113, p. 119.

mum expansion is reached, so that 7 c.c. of dry ethylene gave, after decomposition, 12·25 c.c. They noted also that the residual hydrogen had an unpleasant smell, and burnt with a slightly luminous flame.

Berthelot,[*] in 1869, claims that ethylene breaks up under the influence of heat into acetylene and hydrogen, as expressed by the equation

$$C_2H_4 = C_2H_2 + H_2,$$

and shows that the acetylene then polymerises into benzene, styrene, and other liquid products of higher boiling points. Naphthalene was also formed by the direct condensation of styrene and acetylene. He also points out that during the heating of ethylene a large proportion of ethane was formed, and his final conclusion is that the heating of ethylene results in the splitting up of 2 mols. of ethylene into acetylene and ethane, and that the formation of solid and liquid products is due to the subsequent condensation of the acetylene.

In 1886[†] Day made a number of experiments in order to determine the lowest point of temperature at which the constitution of ethylene undergoes alteration, and the nature of the changes taking place at that temperature. In order to do this, he devised an ingenious apparatus in which the ethylene could be heated for very long periods in a hard-glass tube. From these experiments he concluded that when the action is continued over a long period the gas undergoes change at much lower temperatures than had been previously observed. The alteration in constitution commences at about 350° C., at which temperature the change is one of condensation without the formation of members of any series of hydrocarbons having a percentage of hydrogen and carbon different from ethylene, whilst if ethylene is maintained at 400° for a sufficient length of time, it is entirely decomposed, marsh gas, ethane, and liquid products being obtained.

In the same year Messrs. Morton and Noyes[‡] made an elaborate investigation with the object of determining whether crotonylene, C_4H_4, which is present in small quantities in illuminating gas and other products of the distillation of organic matter, is formed as a primary product of decomposition by heat, or as a secondary product of the action of heat upon ethylene.

Coal gas was passed slowly through a hard glass tube 15 mm. in diameter, which was maintained at a low red heat for a distance of 60 cm. The products issuing from this tube were first passed through a series of ∪-tubes surrounded by a freezing mixture; the products which were not condensed were passed through an ammoniacal solution of cuprous chloride, to absorb hydrocarbons of the

* 'Annales de Chimie et de Physique,' 4th series, vol. 16, p. 144.
† 'American Chemical Journal,' vol. 8, p. 153.
‡ Ibid., vol. 8, p. 362.

acetylene series, whilst samples of the gases escaping absorption were finally collected over water. Carbon was deposited in the decomposition tube, and at the end of one month 15 c.c. of liquid had been slowly condensed in the U-tubes, and in this liquid they detected benzene, naphthalene, anthracene, and some other aromatic hydrocarbons, present in quantities too small for determination. Faint traces only of precipitate were found in the ammoniacal cuprous chloride solution, whilst among the bodies absorbed by bromine they identified crotonylene tetrabromide, and the gas collected over water proved to be a mixture of methane and ethane. The absence of acetylene from the products obtained led them to the view that these products are formed directly by the action of heat upon ethylene.

From the work of the earlier observers, the text-books have accepted the equation

$$1. \quad C_2H_4 = C_2 + 2H_2$$

as representing the decomposition which takes place at a very high temperature, whilst, on the evidence of the work done by Marchand, and Buff and Hofmann, they represent the change taking place at a lower temperature by the equation

$$2. \quad C_2H_4 = C + CH_4.$$

During my attempts to trace the actions taking place in the inner zone of luminous flames, I was struck by the complexity of the changes, and the absence of any evidence which would tend to confirm the second equation, and I have made the experiments detailed in the following paper in the hope of being able to trace the decomposition effected by heat in such simple hydrocarbons as ethylene, ethane, and methane.

The first step was to make experiments to corroborate the statement made by Day that, if ethylene is heated at 400° C. for a sufficient length of time, it is entirely decomposed, with formation of methane, ethane, and liquid products.

In order to do this an apparatus of the form used by Day in his experiments was employed, the only difference being that instead of using an air thermometer, the temperature was taken by means of a platinum and platinum-rhodium couple—as introduced by Le Châtelier, and fully described by Mr. C. Roberts-Austen—which had been previously carefully calibrated, employing salts of known fusing points. The ethylene was prepared for this and for all the following experiments by making a mixture of 25 parts by weight of rectified methylated spirit and 150 parts of strong sulphuric acid. The mixture was heated in a flask containing a layer of sand, and the gas evolved was washed by contact with strong sulphuric acid, and by passage through several bottles containing a strong solution of caustic soda. The gas was stored in a glass gas-holder for several days over water

containing sodic pyrogallate and sodic hydrate, to absorb all traces of oxygen, and on analysis gave

Ethylene.......... 98·80
Nitrogen.......... 1·20

The gas was then passed through the combustion tube, until it was considered that all air had been displaced, and the tube was maintained for 100 hours at 400° C. Oil and a very small quantity of carbon deposited in the tube, and the volume decreased from 100 to 61. The gas was then removed from the tube and analysed.

In all the analyses described in this paper the following procedure was adopted. Carbon dioxide was absorbed by means of a 50 per cent. solution of sodic hydrate, the oxygen estimated by absorption with alkaline pyrogallate, the unsaturated hydrocarbons next absorbed by means of a solution of bromine in potassium bromide, care being taken to remove bromine vapour from the gas by agitation with caustic soda before measurement, the carbon monoxide was next estimated by acid cuprous chloride, and after removal of any acid fumes the residual gas was treated with paraffin oil, previously prepared for use by heating it over a water-bath for at least an hour.

Experiments show that in the case of mixtures of methane with higher members of the same group, agitation with paraffin prepared in this way, or mere standing in contact with it with occasional agitation for twenty to thirty minutes, will remove the ethane and any higher saturated hydrocarbons which may be present, together with a small proportion of the methane. The amount of residual methane can then be determined by explosion with oxygen, and subsequent estimation of the carbon dioxide formed, the volume of gas absorbed by the paraffin *plus* the volume resulting from explosion giving the total volume of saturated hydrocarbons. Details of the results obtained by this method of procedure when dealing with gaseous mixtures of known composition will be found, ' Jour. Soc. Chem. Industry,' vol. 10, p. 407.

The analysis of the heated ethylene gave

Carbon dioxide.......................... 0·82
Oxygen .... 0·00
Unsaturated hydrocarbons............... 7·00
Carbon monoxide........................ 1·17
Saturated hydrocarbons—Paraffin.. 40·18 } 61·82
                          Explosion 21·64 }
Hydrogen............................... 22·18
Nitrogen............................... 7·01
                                        ————
                                        100·00

the oxides of carbon and increase on the nitrogen showing that some air had remained in the tube.

A second analysis was now made, but instead of estimating the saturated hydrocarbons by first absorbing the higher members and some methane by paraffin, they were exploded with oxygen, and the methane calculated from the carbon dioxide amounted to $112 \cdot 5$ per cent., showing that ethane and probably even higher members of the series were present, results which fully bear out the statement made by Day as to the decomposition of the ethylene taking place at a temperature of 400° C., and also the statements made by Berthelot and by Day, that under the conditions of this experiment ethane or at any rate higher members of the C_nH_{2n+2} series are formed as well as methane.

It would, however, be manifestly wrong to assume that the formation of the higher paraffins was a primary action, as keeping the hydrocarbons formed by the primary changes at a temperature of 400° C. might easily lead to the formation of secondary products by interaction between the gases.

It seemed much more probable that the character of the primary decompositions would be ascertained by rapidly heating the gas, and as rapidly removing the products of decomposition from the influence of heat, and that this would be effected by passing a regular current of the gas through a very narrow tube heated for 140 mm. to a known temperature.

The necessity for heating this tube to temperatures above 1000° C. practically limited the choice of material of which it could be made to fire-clay or platinum. It was at first feared that the use of the latter might interfere with the changes taking place, but a long series of comparative experiments, in which ethylene was decomposed by passing through (a) a pipe-stem glazed with borax, and (b) a platinum tube 2 mm. in diameter, both being heated to the same temperature, showed that the platinum tube was free from experimental objection unless a considerable percentage of oxygen was present, and that, even with a new tube, the decompositions were of the same nature as when the pipe-stem was employed.

Under these conditions the platinum tube possessed so many advantages over the clay pipe that in all the subsequent experiments a platinum tube, 2 mm. in diameter and about 40 cm. in length, was used, and, in order to accurately measure the temperature to which the gas in the tube was heated, the following arrangement was devised :—

Ethylene was stored in a gas-holder, and, after passing over calcic chloride to dry it, entered the platinum tube. In this tube the platinum and the platinum-rhodium thermo-couple was arranged in the following fashion :—

The two wires are twisted together for a length of 3 mm., and the wires on either side of the twist are then passed through thin glass tubes, which are fused on to them; having been in this way coated with glass so that only the twist is exposed, they are passed through the platinum tube, the glass insulating the wire from the tube, and also keeping the thermo-junction in such a position that it registers the temperature of the gas in the tube, not that of the wall of the tube.

To each end of the platinum tube glass T-pieces are fitted, down the stems of which the wires pass to mercury seals; from the metal seals conducting wires lead to the resistance coils, the key, and a reflecting galvanometer. The products, after leaving the platinum tube, pass through a U-tube, cooled in ice and salt in order to condense any liquids, and then through a collecting tube, from which the sample of gas for analysis for gas is taken, thence to Volhard absorption flasks (containing ammoniacal silver nitrate for the estimation of acetylene), the flow of the gas through the apparatus being regulated by means of the aspirator bottle.

In the following set of experiments the ethylene, after purification from oxygen by standing over a dilute solution of sodic pyrogallate and sodic hydrate, was passed through the tube at the rate of about 10 c.c. per minute.

These experiments are of considerable interest, as they throw some light upon the changes taking place during the heating of ethylene.

The gas being passed through 140 mm. of heated tube, no change takes place until a temperature of 800° C. is reached, when traces of acetylene are observed; between 800° and 900° C. the acetylene increases in quantity, and large quantities of methane are generated, accompanied by liquid products. This action increases until just below 1200° C., when hydrogen begins to appear amongst the products of decomposition, whilst the moment the liberation of hydrogen commences, carbon also is deposited; and the formation of oil decreases until close upon 1500° C., when the decomposition of the ethylene is practically complete, and the products of decomposition are mainly hydrogen with some undecomposed methane, and a copious deposit of carbon.

In each experiment the products of decomposition were examined to see if any member of the C_nH_{2n+2} group other than methane was present, and in no case could any be detected. This seems to point strongly to the conclusion that the ethane formed in the previous experiment, in accordance with the experiments of Day and Berthelot, had its origin as a secondary, and not as a primary, product of decomposition, but it was clear that to determine this point other experiments must be made, to see if under these conditions of tem-

Table I.—The Action of Heat upon flowing Ethylene.

Percentage of ethylene in original gas.	96·78	96·78	96·78	94·8	94·8	98·91	98·91
Temperature of gas in decomposing tube	600° C.	700° C.	800° C.	900° C.	1000° C.	1200° C.	1500° C.
Analysis of gas after heating, per cent.							
Unsaturated hydrocarbons........	96·42	96·39	96·46	34·77	18·02	10·54	0·43
Containing acetylene..	0·00	0·00	trace	0·82	0·60	3·60	0·00
Saturated hydrocarbons .	0·00	0·00	0·00	59·73	76·48	55·26	27·80
Hydrogen....	0·00	0·00	0·00	0·00	0·00	25·11	62·68
Carbon deposited and oil formed in grams per 100 c.c.							
Carbon......	0·00	0·00	0·00	0·00	0·00	0·0273	large quantity
Oil	0·00	0·00	0·00	0·0024	0·0048	0·0038	0·00
Change of volume	none	none	none	decrease	decrease	increase	large increase

perature a slower rate of flow was attended by generation of any saturated hydrocarbons higher than methane.

In order to do this, the same arrangement of apparatus was employed, but the rate of flow of ethylene was diminished to 4·2 c.c. per minute, the gas, after heating, being collected as before, and an analysis made in which the saturated hydrocarbons were calculated from the results of the paraffin absorption and subsequent explosion. A second analysis was then made of the heated gas without any paraffin absorption, and the volume of carbon dioxide formed on explosion calculated as methane. If the volume so obtained is found to be greater than that originally given by the combined paraffin absorption and subsequent explosion, it is held to be evidence that some higher member of the paraffin series must be present. In order to ascertain if any unsaturated hydrocarbon other than ethylene is present in the gas after heating, a sample of the gas is exploded with oxygen, and the carbon dioxide estimated; should the amount formed exceed the carbon dioxide calculated from the second analysis, it may be taken as evidence that an unsaturated hydrocarbon higher than ethylene is present.

Analysis of the Ethylene used in these experiments.

Carbon dioxide...............	Nil
Oxygen	0·24
Ethylene...................	98·55
Nitrogen...................	1·21
Methane...................	Nil
Hydrogen	Nil
	100·00

Table II.—The Action of Heat upon Ethylene flowing at the rate of 4·2 c.c. per minute through 6 in. of heated tube.

I. Analysis of heated gas made with paraffin absorption and explosion.

Temperature of gas in tube	800° C.	900° C.	1000° C.	1200° C.
Unsaturated hydrocarbons ...	91·90	84·31	45·31	18·31
Saturated hydrocarbons—				
By paraffin	1·63 } 2·23	5·00 } 6·48	6·71 } 30·11	4·56 } 28·57
By explosion....	0·60	1·48	23·40	24·01
Hydrogen	3·26	4·67	19·65	49·51
Carbon monoxide.	1·11	1·40	1·23	1·10
Carbon dioxide...	nil	nil	nil	nil

II. Analysis of heated gas made without paraffin absorption.

Unsaturated hydrocarbons...	92·0	84·15	45·72	18·20
Methane calculated from CO_2..	4·1	10·25	34·11	28·79
Carbon monoxide .	1·2	1·50	1·28	1·0

III. Carbon dioxide from total explosion.

Calculated from Analysis II	189·3	180·7	129·2	69·31
Found	190·0	182·4	133·4	69·00
Carbon deposited in tube, grams per 100 c.c. of gas	trace	trace	0·0101	0·2150
Oil formed per 100 c.c................	0·012		0·0573	0·0035
Vol. of gas before heating	521·7	lost	514	350
Vol. of gas after heating	469·1		460	470

These experiments show conclusively that when only flowing slowly through the tube a higher member of the paraffin group, probably ethane, is formed up to 900° C., whilst at 1000° C. the quantity has

rapidly diminished, and at 1200° C. methane is the only member of the series present.

In the same way a small trace of some unsaturated hydrocarbon, probably benzene, is present at the lower temperatures, but disappears when 1200° C. is reached.

The next step was to see if the action of heat upon ethane under the same conditions as those existing in the previous set of experiments bore out the results arrived at.

Ethane was prepared by acting on ethyl iodide with a copper-zinc couple in presence of water, and passing the evolved gas through fuming sulphuric acid to purify it.

Table III.—The Action of Heat upon flowing Ethane.

Percentage of ethane in original gas .	96·38	96·38	96·38	96·38
Temperature of gas in the decomposing tube	900° C.	1000° C.	1200° C.	1500° C.
Analysis of the gas after heating—				
Unsaturated hydrocarbons........	31·00	28·42	11·58	1·69
Containing acetylene	trace	0·30	1·80	0·91
Saturated hydrocarbons—Paraffin .	12·82	8·34	3·88	0·00
Methane.	12·01	12·73	21·86	20·62
Hydrogen.......................	40·64	46·78	57·45	73·35
Carbon deposited and oil formed in grams per 100 c.c. of gas—				
Carbon	0·0	0·0	0·0126	0·0314
Oil...........................	0·0	trace	trace	0·0

These results show that, even below 900° C., ethane decomposes with liberation of hydrogen and formation of unsaturated hydrocarbons, which on examination prove to consist of ethylene with small quantities of acetylene, rise of temperature completing this decomposition, and also causing the ethylene to decompose as before.

It is evident that, if ethane had been a primary product in the decomposition of ethylene, it would in turn have decomposed with liberation of hydrogen at or below 900° C., and hydrogen would have been found at that temperature as a product of the decomposition of the ethylene instead of its appearance being coincident with the deposition of carbon at 1200° C.

The fact that with a rapid flow I was unable to detect a trace of free hydrogen until carbon has begun to deposit, or *vice versâ*, shows the fallacy of the text-book equation

$$C_2H_4 = CH_4 + C,$$

and on examining the evidence upon which the statement is based we find that Marchand,[*] who originated it, passed ethylene through glass and earthenware tubes heated to redness, and analysed the resulting

[*] 'Journal für prakt. Chemie,' vol. 26, p. 478.

products by passing them over heated copper oxide, and estimating the carbon dioxide and water vapour formed. At first the proportion of carbon to hydrogen was 100 to 17·236, which corresponds to nearly pure ethylene, and on heating to a higher temperature the ratio altered to 100 carbon to 30·771 hydrogen, which nearly corresponds to methane, carbon being at the same time deposited ; but this is manifestly no proof of the gas being methane, as a mixture of undecomposed ethylene and hydrogen, or mixtures of ethylene, methane, and hydrogen, such as those formed at 1200° C., would give the same result.

His results were to a certain extent confirmed by Buff and Hofmann, who noticed that when the platinum spiral was heated in pure ethylene there was at once a deposition of carbon, whilst the gas scarcely expands, from which they concluded that methane had been formed at the same time. When, however, the experiments tabulated in Table I are examined, it will be seen that as soon as 1200° C. is reached and carbon is deposited expansion takes place ; but that at all temperatures short of that there is contraction due to some of the gaseous products undergoing polymerisation and yielding liquids. In Buff and Hofmann's experiment the gas in contact with the incandescent wire was decomposed with liberation of hydrogen and separation of carbon ; but the expansion caused by this action happened to be nearly equalised by the contraction due to polymerisation in the less heated portions of the gas.

The simultaneous appearance of carbon and hydrogen indicates clearly the liberation being due to the splitting up of a hydrocarbon, and the proportion in which these elements are liberated point to acetylene as being the body concerned.

In a paper read before the Chemical Society* I showed that in the interior of a luminous flame the olefines are to a great extent converted into acetylene, which decomposes at about 1200° C. with liberation of carbon, which, being heated partly by its own combustion and partly by the combustion of methane and hydrogen, becomes incandescent, and gives luminosity to the flame, and in the experiments which I have described I fully expected to find a higher percentage of acetylene; but the great tendency towards polymerisation which that body exhibits seems to at once determine its conversion into benzene, which can readily be distinguished among the liquid products, whilst a number of other more complex hydrocarbons are produced, among which crystals of naphthalene are conspicuous.

In order to ascertain if the behaviour of acetylene when passed through the heated tube under the conditions of these experiments gave results which support this view, acetylene was prepared by the action of dilute hydrochloric acid on acetylide of copper.

* 'Chem. Soc. Jour.,' vol. 61, p. 322.

Analysis of Original Gas.

Acetylene...................... 94·28
Oxygen .... 1·12
Nitrogen...................... 4·60

The gas was passed through the platinum tube, 25 mm. of which was heated to a temperature of 1000° C.

Analysis of the Heated Gas.

Acetylene .... 25·95
Other unsaturated hydrocarbons . 61·97
Saturated hydrocarbons .... 3·21
Carbon monoxide .... 1·01
Oxygen .... 0·38
Hydrogen...................... 1·50
Nitrogen...................... 5·98
                                _____
                                100·00

Carbon and Oil formed per 100 c.c. of gas.

Oil .... 0·095
Carbon .... 0·018

Volume before heating.... 309 c.c.
„   after   „   .... 174·2 c.c.

showing that even under these conditions nearly three quarters of the acetylene had undergone polymerisation, so that it is probable that in the case of nascent acetylene, liberated from ethylene by the action of heat, the condensation of the acetylene molecules to form benzene would be practically instantaneous, unless the temperature were sufficiently high to cause dissociation to carbon and hydrogen at the moment of liberation.

The unsaturated hydrocarbons consisted chiefly of ethylene with some benzene vapour, the ethylene probably having been formed by the direct combination of acetylene and hydrogen, an interaction first noticed by Berthelot,

$$C_2H_2 + H_2 = C_2H_4.$$

This also accounts for the small quantity of free hydrogen found on analysis, which, having regard to the amount of carbon deposited, should have been considerably higher.

It will be noticed that with the rate of flow employed in the experiments shown in Table I, the largest amount of acetylene found in the gas after heating was 3·60, which occurs just at the temperature when carbon begins to deposit freely, and is therefore sufficiently

high to check the polymerisation of the acetylene, and many attempts were made to find conditions under which the acetylene could be liberated and prevented from polymerising, and it was found that this could apparently be, to a certain extent, effected either by diluting the ethylene with a considerable volume of an inert gas, or else increasing the rate of flow through the heated tube.

On passing a mixture of 75 per cent. hydrogen and 25 per cent. ethylene through the tube, heated as before, 3·43 per cent. of acetylene was produced, which would be equivalent to 13·72 on the ethylene present, whilst the following results show the effect of increasing the rate of flow of the gas through the tube. The original gas taken was a bad sample containing 87·49 per cent. of ethylene and 12·51 of nitrogen, and the rate of flow was increased to 15 c.c. per minute, the tube being heated to 1250° C.

Unsaturated hydrocarbons.....................	10·41
,, ,, containing acetylene .	4·49
Saturated hydrocarbons......................	34·00
Hydrogen...................................	41·99
Nitrogen...................................	9·11
	100·00

Increase in volume ....   Large
Carbon and oil deposited.. ..   0·006 gram per 100 c.c.

showing a very marked increase in the amount of acetylene formed.

Before it was possible to trace the primary action taking place during the heating of ethylene, it was necessary to find how the temperatures and methods I was employing affected pure methane, which plays so important a part amongst the products of decomposition.

Methane was prepared by acting on methyl iodide by means of the copper zinc couple in the presence of alcohol and water.

Table IV.—The action of Heat upon flowing Methane.

Percentage of methane in the original gas........................	99·2	99·2	99·2	99·2
Temperature of gas in the decomposing tube........................	1000° C.	1200° C.	1300° C.	1500° C.
Analysis of gas after heating—				
Unsaturated hydrocarbons	trace	0·07	0·39	1·20
Containing acetylene	trace	0·07	0·39	0·963
Saturated hydrocarbons..........	97·65	90·00	88·52	19·22
Hydrogen......................	1·55	8·53	10·37	78·66
Carbon deposited and oil formed in grams per 100 c.c. of gas—				
Carbon	0·0	0·0	trace	0·015
Oil...........................	0·0023	0·0025	0·0005	0·0

These results show how much more stable methane is under the influence of heat than any of the other gaseous hydrocarbons studied.

It probably decomposes at first into acetylene and hydrogen, according to the equation

$$2CH_4 = C_2H_2 + 3H_2,$$

and then the acetylene either polymerises or decomposes to carbon and hydrogen, according to the temperature.

These results also explain why it is that the flame of methane when burning at an open tube is practically non-luminous, as, under these conditions, the maximum temperature of the flame is below 1100° C., and no formation of acetylene takes place; whilst with increase of temperature the flame becomes rapidly more and more luminous, so that when burnt in a regenerative burner at 1500° C. the light emitted is of considerable illuminating value.

As a further step in securing factors by which to trace the decomposition, it seemed advisable to attempt to trace the action of heat upon the benzene vapour formed by the polymerisation of the acetylene; and in order to do this, pure hydrogen was allowed to pass through benzene at a known rate and a constant temperature, the amount of benzene in the gas being determined.

Table V.—The Action of Heat upon Hydrogen-borne Benzene.

	5·28	5·28	5·28
Percentage of benzene in original gas	5·28	5·28	5·28
Temperature of gas in the decomposing tube	900° C.	1100° C.	1300° C.
Analysis of the gas after heating.			
Unsaturated hydrocarbons	5·00	3·33	2·43
Containing acetylene	0·00	trace	0·083
Saturated hydrocarbons..................	0·00	2·87	5·02
Hydrogen...............................	95·00	93·80	92·47
Carbon deposited and oil formed in grams per 100 c.c. of gas.			
Carbon	0·0	trace	0·01
Oil.......	trace	0·012	0·00

which shows that the diluted benzene breaks down to acetylene, methane, and carbon, and, finally to carbon and hydrogen.

Taking the experimental data, it seemed to show that the primary reaction on heating ethylene is the splitting up of 3 mols. into acetylene and methane,

$$3C_2H_4 = 2C_2H_2 + 2CH_4,$$

and that the acetylene then polymerises into higher bodies as

$$3C_2H_2 = C_6H_6,$$

and that these compounds, by further polymerisation and interactions amongst themselves, of the kind studied by Berthelot and Carnelley,[*] give rise to a large number of others. As the temperature rises, the methane formed in the primary action splits up into acetylene and hydrogen,

$$2CH_4 = C_2H_2 + 3H_2;$$

and when the temperature has reached the decomposing point of the acetylene, which varies with the degree of dilution, polymerisation takes place no longer, but the acetylene splits up directly into carbon and hydrogen, and all the products formed at lower temperatures doing the same thing, the final reaction is

$$C_2H_4 = C_2 + 2H_2.$$

An attempt was now made to see how far analytical results would quantitatively bear out the inferences deduced from the foregoing experiments.

To do this, the method adopted was as follows:—The whole apparatus was filled with ethylene. The platinum tube and condensing tube were weighed, and the amount of ethylene in the gas holder measured. The platinum tube was heated to the required temperature, and the gas aspirated through it at a uniform rate of 4·2 c.c. per minute. When sufficient gas had passed through (about 250 c.c.) the stopcocks were turned off, and the amount of gas left in the holder measured. The amount of water displaced from the aspirator was also measured, and in this manner the change in volume was determined. The tube was again weighed, and the gain in weight noted. The platinum tube was also weighed, and then slowly heated to dull redness in a stream of hydrogen, in order to drive off any oil that might have been condensed in it, and again weighed. The tube was now heated to bright redness in a stream of oxygen, in order to burn off carbon, and again weighed. The sample tube was closed, and the contents analysed; the acetylene in the absorption bottles was also determined in the usual way.

Ethylene was first heated to 700—800° C., but no acetylene was formed, no alteration in volume took place, and the gas seemed unacted upon.

The temperature was then raised to 800—900° C., and the following results obtained.

Oil................	0·0131 gram per 100 c.c. gas.
Heavy oil.........	0·0055 „ „
Carbon	Nil
Decrease in volume	100 to 89
Acetylene formed .	0·057 per cent.

[*] 'Chem. Soc. Journ.,' vol. 37, p. 701.

On analysis the gas gave—

1. Acetylene	0·06	
Unsaturated hydrocarbons	81·38	
Paraffins	6·66	⎫ 15·83
Marsh gas	9·17	⎭
Hydrogen......................	0·00	
Nitrogen......................	3·10	
	100·37	

Original gas—

Ethylene......................	98·03
Nitrogen......................	1·97
	100·00

Analysis without paraffin absorption—

2. Acetylene.....................	0·06
Unsaturated hydrocarbons	81·25
Saturated hydrocarbons	17·70
Hydrogen......................	0·00
Nitrogen......................	3·10
	102·11

0·0186 gram of oil = 17·3 c.c. of acetylene at 17° C. and 760 mm. 100 vols. of gas after heating condense to 89 vols. gas and 15·4 vols. acetylene.

Calculating the analysis from a percentage to a basis of 89, we get—

Acetylene.....................	0·05
Unsaturated hydrocarbons	72·41
Saturated hydrocarbons	14·00
Hydrogen	0·00
Nitrogen......................	2·76
	89·22

Taking 72·41 from 98·03 = 25·62 of ethylene decomposed, and, according to the equation $3C_2H_4 = 2C_2H_2 + 2CH_4$, 25·62 should give—

Calculated   17 vols. of acetylene and 17 vols. of methane
Found....   15·4 „   „   14   „   „

the discrepancy in the figures being due to interactions between the products of decomposition, and the result would certainly seem to point to the above equation as representing the initial decomposition.

The next temperature tried was 900—1000° C., and the following figures were obtained :—

Rate of flow........   4·2 c.c. of gas per minute.
Oil................   0·0213 gram per 100 c.c. gas.
Heavy oil ....   0·0080   „   „
Carbon ....   0·0363   „   „
Decrease in volume..   100 to 98·6

On analysis the gas gave—

1. Acetylene.....................   1·19
   Unsaturated hydrocarbons ......   15·21
   Paraffins.....................   12·70 ⎱ 40·48
   Methane.....................   27·78 ⎰
   Hydrogen.....................   41·30
   Nitrogen.....................   1·82
                                   ─────────
                                     100·00

No paraffin absorption—

2. Acetylene ....   1·19
   Unsaturated hydrocarbons ......   15·43
   Saturated hydrocarbons.........   40·77
   Hydrogen ....   40·79
   Nitrogen.....................   1·82
                                   ─────────
                                     100·00

Explosion of the whole—

Carbon dioxide................   73·73 per cent.
  „   „   calculated from 1 73·28   „
  „   „   „   „ 2 73·96   „

0·0363 gram of carbon = 36·3 c.c. of acetylene at 19° C. and 762 mm.

0·0293 gram of oil = 27·0 c.c. of acetylene at 19° C. and 762 mm.

Calculating these from 100 c.c. of gas to 98·6 c.c. of gas, we get—

Oil   = 26·8 c.c. of acetylene at 19° C.
Carbon = 35·8 c.c.   „   „

And calculating the gas analysis in the same manner as before, we obtain :—

Acetylene ....   1·17
Unsaturated hydrocarbons ......   15·00
Saturated hydrocarbons ....   39·90
Hydrogen.....................   40·72
Nitrogen ....   1·81
                                 ─────────
                                    98·60

Then the amount of ethylene decomposed is $98\cdot03 - 15\cdot00 = 83\cdot03$, and this should give

$$3C_2H_4 = 2C_2H_2 + 2CH_4.$$

$$\begin{array}{ccc} 83\cdot03 & 55\cdot35 & 55\cdot35 \quad \text{calculated.} \\ & 62\cdot6 & 39\cdot9 \quad \text{found.} \end{array}$$

Evidently, therefore, some of the methane has decomposed, forming acetylene and hydrogen. Amount of methane decomposed $55\cdot35 - 39\cdot9 = 15\cdot45$,

$$2CH_4 = C_2H_2 + 3H_2.$$

$$15\cdot45 \quad 7\cdot72 \quad 23\cdot16$$

Adding this acetylene on to that already calculated for the decomposition of ethylene, we get $55\cdot35 + 7\cdot72 = 63\cdot07$, a figure nearly equal to the acetylene found.

Taking into consideration the complexity of the changes involved and the difficulty in obtaining great accuracy in gas analysis, these results seem to me to prove that the primary action of heat upon ethylene may be represented by the equation

$$3C_2H_4 = 2C_2H_2 + 2CH_4,$$

whilst the final decomposition is as represented by previous observers,

$$C_2H_4 = C_2 + 2H_2,$$

and that between these two extremes there occur a large number of interactions due to the polymerisation of the acetylene formed from the ethylene, and also at higher temperatures from the methane, according to the equation

$$2CH_4 = C_2H_2 + 3H_2.$$

In conclusion, I desire to acknowledge my indebtedness to Mr. F. B. Grundy for the assistance he has rendered me in this investigation.

III. " An Instrument for grinding Section-plates and Prisms of Crystals of Artificial Preparations accurately in the desired directions." By A. E. TUTTON, Assoc. R.C.S., Demonstrator of Chemistry at the Royal College of Science, South Kensington. Communicated by Professor THORPE, F.R.S. Received January 11, 1894.

(Abstract.)

This instrument has been devised in order to replace by a method of precision the difficult, wearisome, and, at the best, only approximate current method of grinding by hand, upon a slightly convex plate of ground glass lubricated with oil or a solvent, the section-plates and prisms of the relatively soft and fragile crystals of artificial preparations which are required for the determination of the optical constants. It is possible by means of it to grind and polish a truly plane surface in any desired direction in a crystal accurately to within ten minutes of arc, an amount of possible error which would exercise no appreciable influence upon the values of the optical constants. This result may be achieved in a small fraction of the time hitherto required by the most successful hand-grinding, and, owing to the provision of a delicate arrangement for suitably modifying the pressure with which the crystal bears upon the grinding plane, with only the very slightest risk of fracturing even a friable crystal. An arrangement is, moreover, provided by which a second surface may be ground parallel, with a like degree of accuracy, to the first. The sections and prisms furnished by the instrument possess the further advantage of being so highly polished as to enable them to be employed directly without cemented cover-glasses for the determination of the optic axial angle and refractive indices, and the values of these constants derived from them are no longer only approximate but precise.

A short but relatively wide hollow cone, differing but slightly from a cylinder, is rigidly supported vertically above a heavy base by three stout pillars and a triangular cross-plate. Within it rest three movable inner axes. The first carries at its upper end a horizontal circle divided into half degrees, reading, with the aid of a vernier, to . minutes, and provided with a fine adjustment; the axis and circle are capable of rotation by a milled ebonite disc carried at the lower extremity of the former. The bore of this axis is cylindrical, and within it the second axis is capable of vertical motion, rotation in the socket being prevented by a rib and groove. The weight of this second axis and all that it carries may be wholly or partially counterbalanced by a pair of levers whose fulcrum supports rest upon the

circle-plate, whose power-arms are weighted, and whose short, curved arms terminate in blunt knife edges which press upwards against a collar fixed to the axis. The levers may be thrown out of action when desired, and the weight of the axis added to by placing small shot or weights in a brass cup carried at the upper end of the axis. This arrangement enables the weight above the crystal to be modified to any extent. Within the second axis slides without rotation the third one, which carries at its lower end the crystal and its means of adjustment. The upper portion of this axis is tapped with a fine screw thread, and the axis can be raised or lowered by a corresponding milled nut. A collimator and telescope, arranged in a horizontal plane at a suitable height for observing the crystal, are provided; they are movable over circular guiding arcs, whose centre lies in the vertical axis of the instrument. Just below the plane of the optical tubes the horizontal grinding disc is supported in a frictionless bearing carried by an adjustable tripod. It is capable of rotation by a suitable whirling apparatus arranged equally on each side of the axle so as to minimise the strain of the band. The disc is of moderately finely-ground, truly plane plate-glass, suitably mounted in a brass frame, and lies upon a second, from which it is readily detachable, so finely ground as to be almost transparent, and which is employed exclusively for giving a final polish to the surface ground by the removable disc. The grinding is under best control when the driving pulley, which is provided with a suitable handle, is rotated by hand, each revolution producing two revolutions of the grinding disc.

The means of adjusting the crystal so that any desired direction in it may be brought perpendicular to the grinding surface are afforded by two circular motions in the form of movable segments rotated by tangent screws, which, in addition to a pair of centering movements, are carried at the lower extremity of the inner vertical axis, and the common centre of which is occupied by the crystal. These circular movements are graduated to read directly to degrees, and easily by estimation to ten minutes. Two interchangeable pairs of them are provided; the planes of motion of one pair are fixed at right angles, while the planes of the other pair, designed for use in more complicated cases of symmetry, may be adjusted at any desired angle to each other by means of a small graduated horizontal circle carried by one of them.

The crystal is attached to the small cross-grooved disc of the crystal holder by a hard and rapidly-setting wax. It is adjusted so that the zone of faces perpendicular to which it is desired to grind a surface, if such a zone is developed, is parallel to the vertical axis. If such a zone is not present, as will happen in monoclinic and triclinic crystals, a prominent zone, whose position with respect to the

principal directions of optical elasticity is known from goniometrical, stauroscopical, and convergent light observations, is first adjusted parallel to the axis and with one or two pairs of faces parallel to one or both of the planes of circular motion, and subsequently by movement of one or both of the segments over the calculated arc or arcs, the desired direction can be adjusted accurately perpendicular to the grinding disc. Provision for setting any face exactly parallel to a circular motion is provided in a special crystal holder which permits of the requisite amount of rotation after the holder is fixed in its socket. The grinding disc is lubricated with a mobile oil incapable of attacking the crystal, so that the reference faces may be preserved for checking the adjustment after grinding. The crystal is brought down near to the grinding disc by lowering the inner axis, and it is then lowered into contact with the disc and the pressure with which it bears during the grinding regulated by manipulation of the levers.

For grinding the parallel surface the crystal, mounted by its ground surface upon a very small glass disc, is enclosed in a receptacle for it in a special crystal holder consisting of two parts screwed together, the crystal downwards so as to pass through a central aperture in the lower portion in which the disc is supported by a very thin annulus. The broad under surface of the upper portion of the holder, against which the glass disc is pressed when the two parts are screwed together, is made truly plane, and can be adjusted accurately parallel to the grinding disc. The disc and crystal may be removed from time to time during the grinding without disturbing the adjustment, so that grinding may be stopped when the section exhibits small rings in its interference figure. Half an hour is ample for grinding and polishing the two surfaces, and it is unusual to break a crystal, provided the left hand is used to control the nearest lever, and thus ascertain by the delicate sense of touch how the crystal is supporting the strain, when the lever may be manipulated, almost involuntarily, accordingly.

Prisms are quite as readily ground and polished. It is possible in most cases to grind two surfaces symmetrically inclined to a plane of optical elasticity and with the edge of intersection parallel to an axis of optical elasticity, by suitable adjustment of the crystal with the aid of the movements provided and with reference to existing faces.

IV. " An Instrument of Precision for producing Monochromatic
Light of any desired Wave-length, and its Use in the
Investigation of the Optical Properties of Crystals." By
A. E. TUTTON, Assoc. R.C.S., Demonstrator of Chemistry
at the Royal College of Science, South Kensington. Com-
municated by Professor THORPE, F.R.S. Received January
11, 1894.

(Abstract.)

This instrument enables the whole field of any optical instrument
whose aperture does not exceed 2 ins. to be evenly and brightly
illuminated with monochromatic light of any desired wave-length.
It has been devised especially for use in connexion with the axial
angle polariscopical goniometers, spectrometers, stauroscopes, micro-
scopes, and other instruments employed for the investigation of the
optical properties of crystals, but is capable of much more extensive
application. It was suggested by the apparatus described by Abney
(' Phil. Mag.,' 1885, vol. 20, p. 172), but differs from that arrange-
ment in most of its details, and particularly in the employment of a
fixed instead of a movable exit slit, of a rotatory instead of a fixed
dispersing apparatus, which is capable of accurate graduation for the
passage of rays of definite wave-lengths through the exit slit, and in
the manner of utilising the issuing line of monochromatic light,
which, instead of being directed upon an opaque white screen, is
diffused so as to be evenly distributed over the field of the observing
instrument when that instrument is placed directly in its path.

The instrument resembles a compact spectroscope in appearance,
and is constructed to pass a large amount of light. Upon a strong
stand, furnished with levelling screws, a fixed horizontal circle,
carrying a vernier, is supported. About this circle two exactly
similar optical tubes are capable of counterpoised rotation; they
carry at the ends nearest the centre of rotation corrected lens combin-
ations of 2 ins. aperture and only 9 ins. focal length, and at the
other ends a special form of slit, capable of accurate adjustment to the
foci of the lenses by rack and pinion movement. The lenses of each
combination are not cemented together by balsam, but are held in
metal frames, separated by a small air-space, so that they cannot be
injured by the heat rays from a powerful source of light, and no
alum cell is required. The slit-jaws are capable of equal movement
on each side of the central line, so that, however wide the aperture, its
centre remains fixed. They may also be removed altogether and re-
placed by a slider carrying two or three slits whenever it is desired to
use composite light; upon replacement they are made to fall exactly into

their former places, so that their adjustment is unimpaired. A large width of slit, 1 in., is provided for use when imperfectly transparent crystals are under observation whose dispersion of the optic axes for different colours is small, so that a slight curvature of the lines of light vibrating with the same wave-length is immaterial; but stops of $\frac{5}{8}$, $\frac{1}{2}$, $\frac{3}{8}$, and $\frac{1}{4}$ in. respectively are also provided, the two smaller of which are intended for general use, and furnish lines apparently perfectly straight. Above and parallel with the fixed circle a second one, which is divided and carries the dispersing apparatus, is capable of rotation. The latter consists of a single 60° prism with truly worked and specially large faces, $4\frac{1}{2}$ ins. by $2\frac{1}{2}$ ins., in order to fully utilise the light from the 2-in. objective. A single prism is of advantage for the purpose in view, affording more light and the minimum curvature of spectral lines; in order that the dispersion shall not suffer thereby, the prism is constructed of dense glass possessing the highest dispersion compatible with perfect freedom from colour, and which will enable the whole of the visible spectrum to be brought between the edges of the exit slit by rotation of the prism without materially sacrificing light by reflection.

As the optical tubes are exactly similar, either may be chosen as collimator. To a tapped annulus projecting from the slit frame of the one chosen the carrier of an adjustable mirror is attached, and sunlight reflected along the axis of the tube. The other optical tube is then converted into a telescope by the similar attachment of one of three provided eyepieces, which are constructed to focus the edges of the slit immediately in front. The clearly-defined edges thus serve the purpose of a pair of cross-wires between which any solar line may be adjusted. By arranging the prism and telescope so that the beginning of the ultra-violet is adjusted centrally for minimum deviation, it is possible by rotation of the prism to bring the whole of the spectrum past the exit slit. The readings of the prism circle are then taken for the positions when prominent solar lines are adjusted between the closely-approximated edges of the slit, and these readings supplemented by those for the red lithium and green thallium lines, and the whole expressed in a table and by a curve. The mirror and eyepiece are then removed.

Upon illuminating the receiving slit with any artificial source of illumination, light of any wave-length may be made to issue from the exit slit by setting the circle to the reading corresponding to that wave-length. Either the electric arc, limelight, or improved burner and zirconia mantle of the "incandescent gaslight" may be employed, best in a lantern, the condensers of which are sufficient for condensing the rays upon the slit. The opening of the latter need not exceed $\frac{1}{75}$ in. with the feebler of the three sources, and that of the exit slit may be still finer. If either of the two first-mentioned

sources are employed, the apertures may be exceedingly fine, and the monochromatism is of very high order.

To diffuse the issuing light, a tube of 2 ins. diameter and equal length, carrying within it either of two diffusing screens of ground glass, of fine and extremely fine texture respectively, is attached to the tapped annulus of the frame of the exit slit by a suitable carrier, which enables the tube to be approached as near to the slit as desired by sliding along a bar. The instrument to be illuminated, the polariscope of the axial angle goniometer for instance, is brought close up, so that the end of the polarising tube enters the diffusing tube and almost touches the ground glass screen, which is best distant about 1½ ins. from the slit; the axes of the optical tubes of the two instruments should of course be made continuous. The illumination of the field of the polariscope, when carrying an adjusted crystal section-plate between its convergent lens systems, is so bright that measurements of the optic axial angle can be carried out with light as far as G, and is greatly superior to that obtained by the use of coloured flames. The interference figures are wonderfully sharp upon a homogeneously coloured and illuminated background.

Cases of crossed axial plane dispersion can be completely traced from the extreme separation of the axes for red in one plane to their extension for blue in the plane at right angles, and the exact wavelength for the crossing point when the biaxial crystal simulates an uniaxial one at once determined.

The instrument is equally adapted for use in the determination of refractive indices by the methods of refraction or total reflection; the refracted images of the slit of the spectrometer are immensely brighter than when coloured flames or a hydrogen Geissler tube are employed. A great saving of time is effected in all these measurements, and this is especially advantageous in observations for different temperatures. Full details of the mode of employing the instrument for these various observations, and for its use in stauroscopical determinations of extinction angles, are given in the memoir.

V. "On Hollow Pyramidal Ice Crystals." By KARL GROSS-MANN, M.D., F.R.C.S.E., and JOSEPH LOMAS, A.R.C.Sc. Communicated by Professor JUDD, F.R.S. Received January 4, 1894.

(Abstract.)

I. *The Lava Cavern, Surtshellir.*—At a visit to the lava cavern, Surtshellir (Iceland), in June, 1892, the farthest recess, which contains ice stalactites and an ice pond, was found to be covered on walls and ceiling with ice crystals in the form of hollow hexagonal

pyramids, analogous in shape to the well-known cubic crystals of rock salt. The hollow ice pyramids were, roughly speaking, built in the proportion of base 1 to height 2, and ranged up to about 1 in. diameter of base. They were attached to the wall by their apices, turning their hollow bases towards the interior of the cave. They were only found on those parts where stalactites did not occur. The temperature was $+0.5°$ C. ($+33°$ F.), and, as the cave forms a *cul-de-sac*, the air is perfectly calm. The crystals, having thus evidently been formed from the moisture of the atmosphere, had to be considered as a kind of hoar frost.

II. *Hoar Frost.*—During Christmas week, 1892, similar forms of ice crystals, though on a smaller scale, were found in an unusually fine hoar frost. These forms comprised simple and compound hollow hexagonal pyramids, which were sketched at the time.

III. *Artificial Hoar Frost.*—Experiments had been planned already before Christmas, 1892, for the artificial production of hoar frost. Before so doing, however, it was thought advisable to search for any possible traces of artificial hoar frost in the refrigerating chambers used for the frozen-meat trade in Liverpool. This visit rendered experiments unnecessary, as it yielded a rich harvest of simple and compound forms of similar hollow pyramidal ice crystals. The chambers having been cooled down to $-13°$ C. ($+9°$ F.), it was possible to examine the forms minutely without danger of melting, and photographs and microphotographs were taken by magnesium light.

Similar forms of artificial hoar frost were found in the refrigerating ss. " Hellopes," in Liverpool, and also in the cooling cellars of breweries in Berlin.

[IV. During a severe frost in January, 1894, we found in various parts of Cheshire the same hollow pyramidal ice crystals occurring on the under surfaces of ice crusts covering hollow ruts in clayey soil, and small pools where an air space divided the ice from the water. No ice crystals were found on the sides and bottom of the ruts. There was no trace of hoar frost on adjacent objects. Microphotographs were obtained.—January 31.]

V. *Comparison with other Skeleton Crystals* (*e.g.*, Rock Salt).— Like the " hopper-crystals " of rock salt, the hollow, hexagonal pyramids of ice have to be considered as skeleton crystals. A study of the conditions under which these are formed leads us to distinguish three different types of skeleton crystals :

  a. Those due to overgrowth, *e.g.*, KCl.
  b. Those due to growth at the upper edge in swimming crystals, *e.g.*, NaCl.
  c. Those due to starvation growth, *e.g.*, hoar frost.

VI. *Literature.*—1. In 1697 Camerarius described, amongst hexagonal plates of hoar frost, some slightly depressed in the middle.

2. In 1874 Krenner described and illustrated hollow hexagonal ice crystals found in the ice cave of Dobschau. His remarks on their formation and attachment are, however, quite at variance with our observations.

3. In 1889 Assmann described and illustrated the forms of hoar frost; but his illustrations only show flat fronds growing in one dimension.

VII. *Conclusions.*—1. Water, when changing direct from the gaseous into the solid state, is highly crystalline.

2. The tendency to crystallisation is so strong that in those cases where the area of supply is limited by a wall or other heterogeneous surface, skeleton crystals—hexagonal " hoppers "—are formed, growing away from that wall, even under circumstances of excessively slow growth.

3. Calmness of air seems to be an essential condition for their formation.

4. The natural example of crystallisation of water limited to certain directions is given in hoar frost, showing a very marked tendency to form hexagonal hoppers.

5. From our observations, there can be no doubt as to the identity of the ice crystals of Surtshellir, of the refrigerating chambers and ships in Liverpool, and of the cooling cellars of the Berlin breweries, with natural hoar frost.

Presents, February 1, 1894.

Transactions.

Baltimore :—Johns Hopkins University. Studies in Historical and Political Science. 12th Series. Nos. 1—2. 8vo. *Baltimore* 1894. The University.

Edinburgh :—Geological Society. Transactions. Vol. VI. Part 4. 8vo. *Edinburgh* 1892. The Society.

Leipsic :—Astronomische Gesellschaft. Vierteljahrsschrift. Jahrg. XXVIII. Heft 4. 8vo. *Leipzig* 1893. The Society.

London :—Pharmaceutical Society. Calendar. 1894. 8vo. *London.* The Society.

Vienna :—K.K. Zoologisch-Botanische Gesellschaft. Verhandlungen. Bd. XLIII. Quartal 3—4. 8vo. *Wien* 1893. The Society.

Washington :—U.S. Department of Agriculture. Experiment Station Record. Vol. V. No. 3. 8vo. *Washington* 1893. The Department.

Observations and Reports.

Brisbane :—Meteorological Bureau. Climatological Table. July. —September, 1893. 8vo. *Brisbane;* Meteorological Synopsis. November, 1892—October, 1893. 8vo. *Brisbane;* Table of Rainfall. 1893. 8vo. *Brisbane.* The Bureau.

Mauritius :—Royal Alfred Observatory. Annual Report of the Director. 1891. Folio; Meteorological Observations. 1892. Folio. The Observatory.

Sydney :—Observatory. Meteorological Observations. July, 1893. 8vo. [*Sydney* 1893.] The Observatory.

Washington :—U.S. Naval Observatory. Report of the Superintendent. 1893. 8vo. *Washington* 1893. The Observatory.

Journals.

Agricultural Gazette of New South Wales. Vol. IV. Part 10. 8vo. *Sydney* 1893. Department of Agriculture, Sydney.

American Journal of Philology. Vol. XIV. No. 4. 8vo. *Baltimore* 1893. The Editor.

Astronomy and Astro-Physics. January, 1894. 8vo. *Northfield, Minn.* The Editors.

Braithwaite (R.) The British Moss-Flora. Part XV. 8vo. *London* 1893. The Author.

Buller (Sir Walter L.), F.R.S. [Twenty-three Excerpts from the 'Transactions of the New Zealand Institute,' &c.]. 8vo. [1869–93.] The Author.

Clowes (F.) and J. B. Coleman. Quantitative Chemical Analysis. Second edition. 8vo. *London* 1894. The Authors.

Espin (T. E.) Report of the Wolsingham Observatory for the year 1893. Single Sheet. The Author.

Goodchild (J. G.) [Forty-eight Excerpts from the 'Geological Magazine,' &c.] 8vo. [1883–94.] The Author.

Johnston (R. M.) Reference List of Various Books and Memoirs of Scientific and Social and Economic Subjects, written and published since the year 1873. 8vo. *Hobart* 1893. The Author.

Kops (J.) Flora Batava. Afl. 303—304. 4to. *Leiden* 1893. The Netherlands Government.

Schreiber (Paul) Die Grundgleichungen für Zustand und Zustandsänderung in der Atmosphäre. 4to. [1893.] ; [and Four other Excerpts. 8vo and 4to.] The Author.

February 8, 1894.

Sir JOHN EVANS, K.C.B., D.C.L., LL.D., Vice-President and
Treasurer, in the Chair.

A List of the Presents received was laid on the table, and thanks
ordered for them.

The following Papers were read :—

I. "Further Observations on the Organisation of the Fossil
Plants of the Coal-Measures. Part I. *Calamites, Calamo-
stachys,* and *Sphenophyllum.*" By W. C. WILLIAMSON, LL.D.,
F.R.S., Emeritus Professor of Botany in the Owens College,
Manchester, and D. H. SCOTT, M.A., Ph.D., F.L.S., F.G.S.,
Honorary Keeper of the Jodrell Laboratory, Royal Gardens,
Kew. Received December 30, 1893.

(Abstract.)

1. *Calamites.*—The first part of the paper gives a detailed account
of the vegetative structure of *Calamites,* on the basis of a renewed in-
vestigation, in which special attention has been directed to develop-
mental questions.

The petrified specimens which have formed the chief material for
our observations have their structure preserved in great perfection,
and it has been possible to make a thorough study of their organisa-
tion at various stages of development.

The primary structure of the young stem, before growth in thick-
ness has begun, bears a striking resemblance to that of *Equisetum.*
The stem was jointed, with a whorl of leaves at each node. Although
in the specimens showing structure the leaves have not been found
in connexion with the stem, yet their position is evident, from that
of the leaf-trace vascular bundles, the course of which can be clearly
traced. Their distribution follows the same general lines as in
Equisetum, but shows some additional complications.

In the internode, a single circle of collateral vascular bundles
surrounds a relatively large pith, which is solid in some of the smallest
twigs, but became fistular in all the larger stems.

In comparing the vegetative organs with those of *Equisetum,* it is
evident that only the primary structure of *Calamites* can be taken
into consideration.

One important point to be decided was the nature of the canal, which in both genera accompanies each vascular bundle on its inner side. In *Equisetum* these canals, as is well known, mark the position of the first-formed tracheæ of the wood, which have become disorganised owing to the growth of the surrounding tissues.

We have now proved that the "internodal" canals of *Calamites* are of precisely the same nature. Here also the canals have been constantly found to contain the annular and spiral tracheæ of the protoxylem, which in longitudinal and oblique sections can be recognised with perfect distinctness.

At the nodes the canals are usually interrupted. The primary nodal xylem consists of a girdle of short, often reticulate, tracheæ, and closely resembles the corresponding structure in an *Equisetum*.

The foliar bundles pass out horizontally at the nodes. Their tracheæ are spiral, scalariform, or reticulated.

In many of the specimens the primary cortex is preserved. Its outer layers are usually more or less sclerotic, and in a few cases alternate hypodermal bands of sclerenchyma and parenchyma can be distinguished, as in many *Equiseta*.

On the whole, the primary structure of the stem of *Calamites* is substantially that of *Equisetum*.

In *Calamites*, however, secondary tissues were always added, and are only absent from the youngest branches. We have no evidence for the existence of any Calamite without secondary growth. The process, which went on essentially as in normal Dicotyledons, or Gymnosperms, has been observed at all stages. In the best-preserved specimens the cambium, with the thin-walled phloëm outside it, can be recognised.

The primary medullary rays separating the bundles are in some specimens prolonged, as parenchymatous tissue, through the secondary wood. In the type previously described as *Calamopitus* the principal rays consist of prosenchymatous cells, and the structure approaches that of *Calamodendron*.

In the majority of the typical stems of *Calamites* (= *Arthropitys* of Göppert) the principal rays become bridged over by interfascicular wood. In this case most of the radial series of parenchymatous elements die out towards the exterior, and are replaced by series of tracheæ. The exact manner in which this change takes place is discussed in the paper.

The wood consists of tracheæ, and of small secondary rays, the cells of which are usually upright. The tracheal elements appear not to be vessels, but tracheides; they may attain a length of 4 mm. The pits, which are bordered, are limited to the radial walls of the tracheæ, except in the most internal layers of the wood.

The innermost cells of the primary medullary rays underwent con-

siderable tangential dilatation, allowing of a certain increase in the diameter of the pith.

The cortical tissues attained a great thickness in the older stems, owing to the formation of abundant periderm. In one specimen the first origin of the periderm, by tangential divisions of the inner cortical cells, could be clearly traced.

A periderm-like layer was also formed on the surface of the diaphragms, cutting them off from the medullary cavity.

A number of specimens show the insertion of branches, on a relatively main axis. The branches were placed immediately above the node; often there were several in a whorl. Each branch usually lies between two of the leaf-trace bundles next below. The pith of the branch tapers towards the base, almost to a point, so that it is connected with the medulla of the parent stem by a narrow neck of tissue only. This gives rise to the characteristic conical form of those medullary casts which represent the pith-cavity of the basal portion of a branch.

In favourable specimens the continuity of the primary wood of the branch with that of the main stem can be demonstrated with certainty.

The branches were no doubt normal, not adventitious, appendages, and arose near the growing point. Subsequently both the base of the branch and the parent stem became coated by a common zone of secondary wood.

As the branch is traced, from below upwards, the diameter of the pith becomes larger, the number of the vascular bundles increases in the successive internodes, and the characteristic Calamitean structure is assumed. At a certain distance above the base the dimensions become approximately constant.

Many of the branches were abortive, or were at least cast off at an early age. This is proved by the fact that in many specimens the pith of the branch is enclosed towards the exterior by the secondary wood of the main stem.

From specimens shown to one of us by M. Renault, it appears that the *roots*, which were borne at or below the nodes, had the structure of *Astromyelon.* This fact necessitates a re-investigation of the fossils described under the latter name.

2. *Calamostachys.*—The homosporous *C. Binneyana* is first considered.

The morphology of the strobilus is well known. The axis bears alternate whorls of bracts and of sporangiophores. The bracts are coherent for a considerable distance from their base, forming the horizontal disc. Their free limbs turn vertically upwards, and extend at least as far as the second bracteal whorl above. The number of bracts in each whorl is about 12.

The sporangiophores are in verticils, placed midway between those of the bracts, and are usually about half as numerous in each whorl as the latter.

The sporangiophores are peltate, resembling those of *Equisetum ;* each bears [four sporangia on its lower surface, attached near the edge.

The structure of the axis of the strobilus has been studied in detail.

The central cylinder, or *stele* (which may be either obtusely triangular or quadrangular, as seen in transverse section), has a parenchymatous pith, of considerable relative size, around which are the collateral vascular bundles.

In the triquetrous form their number is 3 or 6; in the quadrangular type it is 4. The bundles are always placed at the projecting corners of the stele. On the inner side of each bundle is a gap, or irregular canal, in which the annular and spiral tracheæ of the protoxylem are contained.

The phloëm is very rarely preserved, but in one specimen could be clearly recognised.

The structure of the bundles, both in the internodes and nodes, is essentially similar to that of *Calamites*, the chief differences consisting in their small number and less definite canals.

In many of the axes a zone of secondary wood, of considerable thickness, was formed.

Vascular bundles pass out into each bract and sporangiophore.

In the latter the bundle forks twice, and each of the four branches runs out, through the peltate expansion, to the base of a sporangium.

The sporangial wall, as preserved, is usually a single layer of cells, which have their walls thickened in a manner resembling that of the " fibrous layer " of some anthers.

The spores are all of one kind. No trace of macrospores was found in any of the numerous strobili of this species which were examined.

The spores attain a diameter of about 0·09 mm. In some specimens they are isolated; in other sporangia they are still grouped in tetrads, each tetrad being enclosed within the wall of the mother-cell.

It is rare for all the four spores of a tetrad to be equally developed. As a rule, one or more of the sister-spores remained very much smaller than their neighbours, and were, to all appearance, abortive. The abortion of these spores must have allowed of an increased nutrition of the survivors, and thus have been of considerable physiological importance.

Calamostachys Casheana, Will., is the heterosporous species. Only two specimens are at present certainly known. The general morpho-

logy and anatomy of the strobilus are similar to, but not identical with, those of the homosporous *C. Binneyana.*

The macrosporangia and microsporangia were borne in the same strobilus, and in one case both kinds of sporangia were found on the same sporangiophore.

The diameter of the microspores is about 0·075 mm.; that of the macrospores is just three times as great.

In the macrosporangia, but never in the microsporangia, numerous abortive spores are constantly found. They are of variable size, but are always much smaller even than the microspores of the same plant. Their invariable presence in the macrosporangia, and equally constant absence from the microsporangia, leave little doubt that they were the abortive sister-cells of the macrospores.

These facts appear to throw some light on the origin of the phenomenon of heterospory in the genus *Calamostachys.* In *C. Binneyana* the abortion of certain sister-cells of the spores, involving the better nutrition of the survivors, had already begun, but still took place equally in all sporangia. In *C. Casheana* the same process, carried further in certain of the sporangia, rendered possible the development of specially favoured macrospores, which attained their relatively large size at the expense of their neighbours, which remained rudimentary. All analogy leads us to suppose that to these macrospores the formation of a female prothallus was entrusted. In the microsporangia no abortion appears to have taken place, and the spores attained a uniform small size.

The axis of the strobilus of *C. Casheana* has a well-marked zone of secondary wood, thus affording direct evidence of the occurrence of secondary growth in a heterosporous Cryptogam.

The affinities of *Calamostachys* are discussed at length. In neither of the species in question has the strobilus been found in connexion with vegetative organs. Other species however, *e.g.,* *C. Ludwigi,* were borne on undoubtedly Calamarian stems.

The fructification of a true *Calamites* has been described in a previous memoir (Williamson, "Organisation of the Fossil Plants of the Coal-Measures, Part XIV," 'Phil. Trans.,' 1888). This strobilus differs from *Calamostachys* in the position of the sporangiophores, which were approximately axillary (instead of being placed in independent verticils, midway between those of the bracts), and also in the anatomy of the peduncle and axis, which was identical with that of the stem of a typical *Calamites.* To this fossil we now propose to give the name of *Calamites pedunculatus.*

The position of its sporangiophores is that characteristic of Weiss's genus *Palæostachya.*

The only *certain* fructification of a *Calamites* thus differs considerably from a *Calamostachys.* The differences, however, are not such

as to preclude a near relationship. A form described by M. Renault, under the name of *Bruckmannia Grand'Euryi*, unites the external morphology of a *Calamostachys* with the anatomy of a *Calamites*. It is therefore possible that the species of *Calamostachys* considered in this paper may have been borne on stems with Calamitean structure, but this cannot be proved until the strobili are found in actual continuity with the vegetative organs.

3. *Sphenophyllum.*—The habit of these plants is well known. The rather slender, jointed stem bore verticils of superposed leaves, the number of leaves in each verticil being some multiple of 3. The leaves were sometimes cuneate, sometimes dichotomously subdivided, sometimes linear.

The anatomy of several undoubted species of *Sphenophyllum* is now known, and there is no longer any doubt that some of the fossils described in previous memoirs under the name of *Asterophyllites* really belong to *Sphenophyllum*.

The first species described is *Sphenophyllum plurifoliatum* = *Asterophyllites sphenophylloides* of the former memoirs.

The number of leaves in each whorl was large, not less than 18. They were linear in form.

The axis is traversed by a solid vascular strand, triangular, as seen in transverse section, without any pith. The strand is triarch, with a group of narrow spiral and reticulate elements (protoxylem) at each angle. The primary wood of the stem was thus centripetal, and so far resembled that of most recent Lycopodiaceæ, with which, however, the genus has otherwise little in common.

Secondary growth in thickness took place constantly, and has been observed at every stage. The secondary wood consisted of radially arranged tracheæ (whether vessels or tracheides is doubtful) with strands of parenchyma between them. The longitudinal parenchymatous strands are connected by radially elongated cells, which, however, seldom form continuous medullary rays.

The cambium is excellently preserved in some specimens, a fact which removes all doubt as to the truly secondary character of the tissues in question.

The primary cortex and leaves were soon cast off by the formation of internal periderm. The older stems have a large amount of secondary tissue to the outside of the cambium. This is shown to consist partly of true phloëm, partly of internal peridermal layers, which in extreme cases formed a regular scale-bark.

A second species, *Sphenophyllum insigne* (= *Asterophyllites insignis*, Will.), is described. Its general anatomy agrees with that of the former species, apart from differences of detail. The most important structural peculiarity of *S. insigne* consists in the constant presence of continuous medullary rays in its secondary wood.

In the phloëm of this species large elements, closely resembling sieve tubes, are found.

The larger specimens, which have lost their primary cortex owing to the formation of periderm, have a very root-like transverse section. Some authors have therefore denied that they belong to *Sphenophyllum*, and have supposed that they are roots of some unknown plant. This is a mistake, for the large specimens have essentially the same structure as the smaller ones, which still retain the characteristic cortex and leaves of a *Sphenophyllum*. The intermediate conditions are also known.

Leaves had not been discovered in this species when the former account of its structure was given, in the earlier memoirs.

The recent researches of M. Zeiller have proved that the fructification previously described (Williamson, " Organisation, &c., Part XVIII," ' Phil. Trans.,' 1891) as *Bowmanites Dawsoni*, is that of a *Sphenophyllum*. In his specimens, strobili, agreeing in all respects with those of *Bowmanites*, are borne on the stems of the well known *Sphenophyllum cuneifolium*, Sternb. The fructification in question must therefore be transferred to the genus *Sphenophyllum*, and is here described under the name of *Sphenophyllum Dawsoni*.

The strobilus consists of an axis bearing numerous whorls of bracts, which are coherent for some distance from their base. The very long sporangiophores arise from the upper surface of the bracts, near their insertion, two sporangiophores corresponding to each bract. At the end of each sporangiophore a single sporangium is borne, which hangs down, parallel to the pedicel, somewhat resembling an anatropous ovule in position.

The axis of the strobilus is traversed by a triarch or hexarch vascular cylinder, essentially similar to that of the vegetative stem of *Sphenophyllum*. At every node vascular bundles are given off to the bracts. Each of these bundles, on entering the verticil of bracts, subdivides into three. The dorsal branch passes straight out into one of the free bracts. The two ventral branches of the bundle supply the two sporangiophores corresponding to the bract in question.

The bundle of the sporangiophore extends through its whole length, becoming thicker towards the apex, where it terminates at the base of the sporangium itself.

The cells of the sporangial wall are of great size near the base, and are very narrow at its opposite end, where dehiscence probably took place.

The spores are numerous in each sporangium, and are all of the same kind. There is at present no conclusive evidence for the existence of a heterosporous *Sphenophyllum*.

The morphological nature of the sporangiophore cannot be determined with certainty. The various possible views are stated in the

paper. For the present it seems best to regard this organ as simply a sporangium-pedicel, though there is no analogy among known Cryptogams for the presence of a vascular bundle in the stalk of a sporangium.

It appears that all species of *Sphenophyllum* in which the fructification is known, had essentially similar strobili, with pedicellate sporangia.

The genus *Sphenophyllum* cannot be placed in any existing family of Vascular Cryptogams. Anatomically there are some striking points of resemblance to Lycopodiaceæ, but the habit and fructification are totally different from anything in that order. *Sphenophyllum*, in fact, constitutes a group by itself, which is entirely unrepresented at the present epoch, and the affinities of which cannot be determined until additional forms have been discovered.

The paper is illustrated by numerous photographs from the actual preparations and specimens, and by a long series of camera-lucida drawings, executed by Mr. George Brebner.

II. "Researches on the Germination of the Pollen Grain and the Nutrition of the Pollen Tube." By J. REYNOLDS GREEN, M.A., B.Sc., Professor of Botany to the Pharmaceutical Society of Great Britain. Communicated by W. T. THISELTON DYER, F.R.S., C.M.G., C.I.E. Received January 2, 1894.

(From the Jodrell Laboratory, Royal Gardens, Kew.)

(Abstract.)

Many observers, especially Van Tieghem and Mangin, have established the fact that the growth of the pollen tube is a process of true germination, strictly comparable to that of the growth of the prothallus from the spore in the groups of Vascular Cryptogams. The germinative process is carried on at the expense of various reserve materials deposited partly in the pollen grain itself and partly in the conducting tissue of the style, down which the pollen tube makes its way.

The existence of certain enzymes in the pollen grain has also been proved by Van Tieghem and by Strasburger. The former has shown that when the pollen of several genera, especially *Crocus* and *Narcissus*, is cultivated in cane-sugar solutions, a certain amount of grape-sugar is produced in the culture, suggesting the presence of invertase; while the latter has shown similarly that certain pollens, when cultivated in starch paste, can liquefy it, with the formation of maltose.

The object of the present research was to isolate these enzymes and to investigate any changes in the amount of either of them during the progress of the germination. Further, to ascertain something of the metabolism going on in both the pollen grain and the style in the interval between pollination and fertilisation.

Both the enzymes were prepared from bruised grains by the use of the ordinary solvents—water, glycerine, and solutions of common salt—the latter being, perhaps, the most efficient. Details of the experiments, and the conditions of extraction, are given in the paper of which this is an abstract. Diastase was found in the resting pollen of various species of *Lilium, Helianthus, Gladiolus, Anemone, Antirrhinum, Tropæolum, Pelargonium, Crocus, Brownea, Helleborus, Alnus, Tulipa,* and *Clivia,* and in that of *Zamia* after germination had begun. The diastase is in the form of the translocation diastase of Brown and Morris. Invertase was found in the pollen of *Helleborus, Narcissus, Richardia, Lilium,* and *Zamia.* Some of these species contained both enzymes.

During the germination of the pollen grain the quantity of both enzymes was found to show a considerable increase in amount, in some cases even four or five fold. This increase was estimated by noting the diastatic or invertive power of extracts prepared side by side, from weighed quantities of pollen, and from equal quantities allowed to germinate in various culture fluids. Control experiments were carried out to show that the increase of enzyme action was not due to a more complete extraction of the ferment from the thin-walled tube than was possible from the thick-walled grain, but that there was an actual total increase of the enzyme. In one case there was noticed a diminution of ferment in the earliest stages of the germination, which may probably be correlated with the digestion of the starch grains of the grain, or of some portion of them, before the output of the pollen tube. It was found, further, that when the power of germination of the pollen grain was becoming feeble, from its being kept for some weeks, there was a very considerable diminution of the amount of diastase that could be extracted. Full details of these experiments are given in the paper.

The mode of growth and nutrition of the pollen tube was investigated by culture of the grain in hanging drops of fluid in a moist chamber, and by chemical analysis of the contents of various pollen grains and styles.

The microscopic examination of pollen tubes revealed general granularity of their contents, with the formation of certain large and refringent granules, that were apparently extruded regularly by the tube at definite places near the top. This appearance has already been noticed by Van Tieghem, to whose work reference is made. The extrusion of these granules suggests that they are the medium

of excretion of the enzyme, which can readily be detected in the culture fluid.

The reserve stores of the pollen grain differ in various species. They include starch, possibly in some cases dextrin, cane sugar, maltose, and glucose. The intracellular action of diastase can be noticed in the cases in which it is present, by the transformation of the starch granules as they pass along the tube, iodine staining them blue in the grain and upper part of the tube, then purple, and finally almost red as the tip is approached; indicating thus the gradually increasing formation of dextrin, one of the accompaniments of starch digestion. Quantitative estimations of the sugars are quoted in detail in the paper.   .

The distribution of starch in the style of the Lily was found to have a close relation to the progress of the pollen tube. The cells lining the cavity of the style, and the cells of the loose conducting tissue abutting on it, were found to contain starch grains, in greater or less amounts, varying with the species and with the age of the individual style. The outer soft tissue of the fibro-vascular bundles of this organ were also charged with crowds of starch grains, indicating a transport of this reserve material from the leaves. Cane sugar, maltose, and possibly glucose, were found to be the sugars present in the various styles examined.

In longitudinal preparations the starch was found to stop short some few mm. below the stigma, suggesting the view that the reserves in the style are intended to supplement those in the pollen grain, the latter being utilised in the early stages of germination.

Not only reserve materials can be found in the style, but in certain cases diastase also exists.

The action of the enzymes of the pollen is thus found to be partly intracellular, digesting the contents of the pollen grain, and partly extracellular, being excreted into the tissue of the style to work upon the external reserves. This is particularly noteworthy in the case of *Narcissus*, where the grain contains invertase, but, according to Van Tieghem, no cane sugar. The latter is found in considerable quantity in the style.

The development of the enzyme is not a phenomenon of starvation. The increased production noted is partly an effect of the absorption of food material which appears to act as a stimulant to its production.

Evidence on this point is quoted in the paper.

The absorption of food material often leads to an increase of starch in the grain and in the tube.

The increase of enzyme noted in certain cases lends a certain amount of support to the view that the enzyme exists in the pollen grain in the form of a zymogen. Some evidence bearing out this

view is derived from some experiments on the pollen of *Zamia*. A watery extract of this pollen was found to have no diastatic power, but on being warmed with a little malic acid for some hours, and then neutralised, it was found to have acquired a feeble one, very slowly hydrolysing some thin starch paste. Further experiments upon this point are, however, necessary before pronouncing decidedly that the zymogen exists.

The whole of the researches may be summarised as under :—

1. Diastase and invertase are both present in pollen grains, and can be extracted from them by the same treatment as has been found effectual in the cases of seeds and foliage leaves. The relative quantities vary à good deal; while some pollens contain both, others possess only one, which may be either of the two.

2. At the onset of germination the amount of both diastase and invertase is usually considerably increased. In one species examined this increase was preceded by a primary diminution. When the pollen grain has lost the power of germinating, the quantity of diastase has considerably decreased.

3. The pollen tube is nourished during its growth by plastic reserve material derived from two sources, the store of material in the grain itself, and a further store deposited in the style.

4. The reserve store of the pollen grain consists of different materials in different species : starch, dextrin, cane sugar, maltose, and glucose being the forms in which it is found.

5. The store in the style consists usually of the same carbohydrates, with the exception of dextrin.

6. The style itself contains enzymes to assist in preparing the reserve materials for absorption by the pollen tube, while the latter excretes the same ferments during its progress down the conducting tissue.

7. The absorption of food material appears to be one cause of the increase of enzyme found to occur during the germination.

8. This absorption of food material is usually so active that the reserve store of the pollen grain is often largely increased by a temporary deposition, either in the grain or its tube, of some of the absorbed sugar in the form of starch.

9. There is a certain amount of evidence pointing to the existence of zymogens in some pollens, particularly such as germinate in a faintly acid medium.

Presents, February 8, 1894.

Transactions.

Berlin :—Gesellschaft für Erdkunde. Zeitschrift. Bd. XXVIII.
No. 4. 8vo. *Berlin* 1893. The Society.

Birmingham :—Philosophical Society. Proceedings. Vol. VIII.
Part 2. 8vo. *Birmingham* [1893] ; [Annual Report.] 1893.
8vo. *Birmingham* [1893]. The Society.

Boston :—Society of Natural History. Memoirs. Vol. IV. No. 11.
4to. *Boston* 1893; Proceedings. Vol. XXVI. Part 1. 8vo.
Boston 1893; Occasional Papers. No. 4. 8vo. *Boston* 1893.
The Society.

Cambridge, Mass. :—Museum of Comparative Zoology. Bulletin.
Vol. XXV. No. 4. 8vo. *Cambridge* 1894. The Museum.

Eastbourne :—Natural History Society. Transactions. Vol. II.
Part 7. 8vo. *Eastbourne* [1894]. The Society.

Genoa :—Società Ligustica di Scienze Naturali e Geografiche.
Atti. Vol. IV. No. 4. 8vo. *Genova* 1893. The Society.

International :—Congrès International d'Archéologie et d'Anthro-
pologie Préhistoriques. 11ème Session, Moscou, 1892. Tome
II. 8vo. *Moscou* 1893.
Société Impériale des Amis des Sciences Naturelles, Moscow.

Kew :—Royal Gardens. Bulletin of Miscellaneous Information.
1893. No. 84 and Appendix 3. 1894. No. 85. 8vo. *London*
1893-94. The Director.

Klausenburg :—Erdélyi Museum-Egylet. Értesitő. Évfolyam
XVIII. Szak 1. Füzet 1. Szak 2. Füzet 1—3. 8vo.
Kolozsvárt 1893. The Society.

London :—British Astronomical Association. Journal. Vol. IV.
No. 2. 8vo. *London* 1894. The Association.

East India Association. Journal. Vol. XXVI. No. 2. 8vo.
London 1894. The Association.

Geological Society. Quarterly Journal. Vol. L. Part 1. 8vo.
London 1894. The Society.

Photographic Society. Journal and Transactions. Vol. XVIII.
No. 5. 8vo. *London* 1894. The Society.

Society of Biblical Archæology. Proceedings. Vol. XV. Part 8.
Vol. XVI. Part 3. 8vo. *London* 1893-94; Transactions.
Vol. IX. Part 2. 8vo. *London* 1893. The Society.

Louvain :—Université. Annuaire, 1894. 8vo. *Louvain;* [Pub-
lications Académiques. 1892-93.] 8vo. The University.

Paris :—École Normale Supérieure. Annales. Tome X. Supple-
ment. 4to. *Paris* 1893. The School.

Société Philomathique. Bulletin. Tome V. No. 4. 8vo. *Paris*
1893. The Society.

Transactions (*continued*).

Siena :—R. Accademia dei Fisiocritici. Atti. Vol. V. Fasc. 7—8. 8vo. *Siena* 1893. The Academy.

Vienna :—K. Akademie der Wissenschaften. Sitzungsberichte. Bd. CII. Abth. 2a. Heft 8. Abth. 2b. Heft 8. 8vo. *Wien* 1893. The Academy.

K.K. Geologische Reichsanstalt. Abhandlungen. Bd. XV. Hefte 4—5. Bd. XVII. Heft 3. 4to. *Wien* 1893; Jahrbuch. Bd. XLIII. Heft 2. 8vo. *Wien* 1893. The Institute.

K.K. Naturhistorisches Hofmuseum. Annalen. Bd. VIII. Nos. 2—4. 8vo. *Wien* 1893. The Museum.

Observations and Reports.

Portugal :—Direction des Travaux Géologiques du Portugal. Description de la Faune Jurassique du Portugal. Classe des Céphalopodes. 1re Série. 4to. *Lisbonne* 1893.

The Director.

Zurich :—Schweizerische Meteorologische Central-Anstalt. Annalen. Jahrg. XXVIII. 4to. *Zürich* [1893].

The Institute.

Journals.

Agricultural Gazette of New South Wales. Vol. IV. Part 2. 8vo. *Sydney* 1893. Department of Mines, Sydney.

Archives des Sciences Biologiques. Tome II. No. 4. 4to. *St. Pétersbourg* 1893.

Institut Impérial de Médecine Expérimentale, St. Petersburg.

Horological Journal. Vol. XXXVI. No. 426. 8vo. *London* 1894. British Horological Institute.

Journal of Comparative Neurology. December, 1893. 8vo. *Granville, Ohio.* The Editor.

Medico-Legal Journal. Vol. XI. No. 2. 8vo. *New York* 1893. The Editor.

Burnham (S. W.) The System of ζ Cancri. 8vo. [1894.] The Author.

Newton (H. A.), For. Mem. R.S. [On the Small Bodies sent off from Comets which form our Shooting Stars.] 8vo. [*Philadelphia* 1893.] The Author.

February 15, 1894.

Sir JOHN EVANS, K.C.B., D.C.L., LL.D., Vice-President and Treasurer, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read:—

I. " On Certain Ternary Alloys. Part VIII. Alloys containing Aluminium, Cadmium, and Tin; Aluminium, Antimony, and Lead; or Aluminium, Antimony, and Bismuth." By C. R. ALDER WRIGHT, D.Sc., F.R.S., Lecturer on Chemistry and Physics in St. Mary's Hospital Medical School. Received January 8, 1894.

In Part VII[*] it has been shown that whilst cadmium can act as "solvent" metal towards either of the immiscible pairs—lead and zinc, bismuth and zinc—this is not the case when aluminium is substituted for zinc, because cadmium and aluminium (contrary to the usual statements in the text-books) are *not* miscible in all proportions, unlike cadmium and zinc. Accordingly, it becomes of interest to examine the behaviour of ternary metallic mixtures where cadmium and aluminium are the two immiscible metals, more especially when a "solvent" metal is employed also capable of use in similar fashion with the immiscible pairs, aluminium and lead, aluminium and bismuth, so as to trace out the effect of substituting cadmium for lead or bismuth. Such a solvent metal is *tin;* the volatility of cadmium, however, precludes the possibility of employing elevated temperatures above the boiling point of that metal (about 770° C.); but, thanks to the physical attraction of molten aluminium for cadmium (comparable with that of water for gaseous hydrochloric acid), it is possible to keep molten in long narrow crucibles metallic mixtures containing simultaneously aluminium and cadmium, without any material amount of volatilisation of the latter metal taking place from the surface of the lighter alloy that floats up (of which aluminium necessarily constitutes the majority), so long as the

[*] Part I, ' Roy. Soc. Proc.,' vol. 45, p. 461; Part II, vol. 48, p. 25; Part III, vol. 49, p. 156; Part IV, vol. 49, p. 174; Part V, vol. 50, p. 372; Part VI, vol. 52, p. 11; Part VII, vol. 52, p. 530.

temperature does not exceed 700° to 750°. At temperatures of 800° and upwards, however, so much cadmium vapour is given off from the heavier alloy (in which cadmium predominates) as seriously to interfere with the experiment, not only because of the alteration in composition thereby produced, but also because of the intermixing effect tending to prevent proper separation by gravitation of the lighter and heavier alloys from one another.

Binary Alloys of Aluminium and Cadmium.

A series of observations was first made to determine the composition of the binary alloys formed when aluminium and cadmium are melted together and well stirred, and then allowed to stand at a temperature of 700—750° (averaging about 725°) for several hours. The following figures resulted as the averages from twelve tolerably concordant experiments :—

	Heavier alloy.	Lighter alloy.
Cadmium	99·78	3·39
Aluminium	0·22	96·61
	100·00	100·00

Hence the solubility of cadmium in aluminium, like that of lead and of bismuth in the same metal, is but small ; whilst the solubility of aluminium in cadmium, like that in lead or bismuth, is inconsiderable, thus—

Temperature.	Solvent.		Percentage.
800° C........	Lead	Aluminium =	0·07
870°	Bismuth ...	„ =	0·28
725°	Cadmium ..	„ =	0·22
800°	Aluminium	Lead =	1·91
870°	„	Bismuth =	2·02
725°	„	Cadmium =	3·39

Mixtures of Aluminium, Cadmium, and Tin.

The alloys were prepared by melting the aluminium, then adding the tin, and finally the cadmium, well stirring as soon as the latter was fluid, pouring quickly into the red-hot clay test-tubes, and maintaining these at 700—750° (averaging about 725°) for from six to eight hours in the lead bath. The analysis was made by dissolving in hydrochloric acid solution containing nitric acid, diluting and precipitating with sulphuretted hydrogen, and separating the tin and cadmium sulphides by means of ammonium sulphide, the tin being

finally weighed as SnO_2, and the cadmium as CdO. The filtrate from the sulphides was precipitated by ammonia, the weight of the Al_2O_3 finally obtained being corrected for traces of iron and silica present. As in all previous experiments, the percentages were calculated on the sum of the weights of the three metals found as 100.

The following average values were deduced from the examination of twelve compound ingots (twenty-four alloys).

No. of tie-line.	Heavier alloy.			Lighter alloy.			Excess of tin percentage in lighter alloy over that in heavier.
	Tin.	Cadmium.	Aluminium.	Tin.	Cadmium.	Aluminium.	
0	0	99·78	0·22	0	3·39	96·61	0
1	4·75	94·84	0·41	2·75	4·45	92·80	− 2·00
2	14·78	84·70	0·52	9·98	4·93	85·09	− 4·80
3	35·98	61·49	2·53	22·28	5·78	71·94	−13·70
4	53·15	40·79	6·06	27·88	6·08	66·04	−25·27
5	57·28	34·26	8·46	37·07	8·18	54·75	−20·21
6	59·18	27·77	13·05	43·17	10·65	46·18	−16·01

Fig. 1 represents these values plotted on the triangular system, the dotted line No. 1 representing the curve obtained at 800° with aluminium-lead-tin alloys (Part VI), and No. 2 that similarly obtained with aluminium-bismuth-tin alloys. The points marked A and B represent two alloys that did not separate, containing respectively,

	Tin.	Cadmium.	Aluminium.
A	72·58	11·37	16·05
B	78·2	10·0	11·8

Obviously the effect of substituting cadmium for lead is to depress the critical curve; it cannot, however, be said with certainty that the same remark applies to the substitution of cadmium for bismuth, although this is probable; for the cadmium curve, being obtained at 725°, is not directly comparable with the bismuth curve obtained at 800°; were the former obtainable with accuracy at 800°, it would doubtless be considerably depressed as compared with the curve at 725°, and would consequently probably lie wholly inside the bismuth curve at 800°; even as it is, the right-hand branch lies inside. In confirmation of this, experiments now in progress with aluminium-cadmium-silver alloys indicate that the critical curve for these alloys lies well inside that with aluminium-bismuth-silver alloys.

Fig. 1.

As regards the direction of slope of the tie-lines, it is noticeable that they are similar in this respect to those obtained with aluminium-bismuth-tin alloys, always sloping downwards to the *right* (*i.e.*, the heavier alloy containing a larger proportion of "solvent" than the conjugate lighter alloy); with aluminium-lead-tin alloys, the lower alloys exhibited a slope to the left, and the upper ones to the right, presumably owing to the formation of a definite compound of tin and lead (probably Pb_2Sn), no analogue of which appears to be produced with either bismuth and tin or cadmium and tin.

Alloys containing Aluminium and Lead (or Bismuth) as Immiscible Metals, and Antimony as Solvent.

It has been shown in Part VII that when antimony is used as solvent metal, zinc and lead (or zinc and bismuth) being the immiscible pairs, the series of conjugate alloys producible are exactly comparable in general characters with the previously described ternary alloys with tin or silver as solvent. Precisely the same remark

applies to the corresponding alloys where aluminium is used instead of zinc, with only this difference, that when the proportion of antimony present exceeds a certain amount the mixtures employed no longer remain completely fluid when kept for several hours at temperatures near 850—900° C.; more or less of the difficultly fusible antimonide of aluminium, SbAl, described in Part VII,* separates out in the solid state; so that in certain cases where the proportion of antimony is large enough to form a " real " alloy a separation of the constituents still occurs in consequence of this action, the compound tending to float up through being lighter than the remaining fluid portion containing the whole of the lead. In consequence, the critical curve indicated by plotting as usual the compositions of the lowermost and topmost portions of the compound ingot ultimately obtained exhibits a sort of excrescence or horn in the central portion, where this abnormal separation occurs. A similar separation by solidification of aluminium antimonide is also observed in the case of alloys containing (in suitable proportions) aluminium, antimony, and some third metal miscible in all proportions with either of them separately; thus with zinc as the third metal, under proper conditions, solid aluminium antimonide separates, the fluid mother liquor, so to speak, consisting of the zinc, together with whatever aluminium or antimony may be present in excess, and such an amount of AlSb as this fused mixture of metals may be capable of permanently dissolving at the particular temperature of the experiment.

Mixtures of Aluminium, Lead, and Antimony.

The following average values were obtained on examination of twenty compound ingots (forty alloys), prepared by fusing together the weighed metals at a temperature above the melting point of silver, and well stirring, pouring into a nearly white-hot clay test-tube, and keeping this for six to eight hours in a lead bath at the highest temperature practicable with the appliances used. This temperature varied between about 850° and 920°, averaging near 880°; even at the hottest, fragments of pure silver did not run down to a liquid, although they fritted together (melting point of silver near 950° C.). The analysis was made in the same way as that of the zinc-lead-antimony alloys described in Part VII, excepting that the acid filtrate from the precipitated sulphides of lead and antimony was directly neutralised with ammonia, the precipitated alumina being weighed, and corrections made for small quantities of F_2O_3 and SiO_2 present.

---

* The existence of this definite compound, described by the author in the ' Journ. Soc. Chem. Industry,' 1892, p. 492, has been since confirmed by D. A. Roche (' Moniteur Scientifique,' 1893, p. 269), who appears to have been unacquainted with the previous work on the subject.

No. of tie-line.	Heavier alloy.			Lighter alloy.			Excess of antimony percentage in lighter alloy over that in heavier.
	Antimony.	Lead.	Aluminium.	Antimony.	Lead.	Aluminium.	
0	0	99·98	0·07	0	1·92	98·08	0
1	1·13	98·49	0·38	3·73	5·06	91·21	+ 2·60
2	5·31	92·61	2·08	14·21	10·90	74·89	+ 8·90
3	9·23	87·69	3·08	22·09	14·43	63·48	+ 12·86
4	15·01	80·05	4·94	30·55	18·33	51·13	+ 15·54
5	21·86	70·29	7·85	38·15	21·23	40·62	+ 16·29
6	27·68	61·68	10·64	47·58	21·88	30·64	+ 19·85
7	37·13	48·39	14·48	54·13	19·33	26·54	+ 17·00
8	44·17	43·05	12·78	55·58	17·70	26·72	+ 11·41
9	50·88	34·89	14·73	60·30	18·10	21·60	+ 9·42
10	53·95	29·50	16·55	62·95	19·15	17·90	+ 9·00

Fig. 2.

Fig. 2 represents these values depicted graphically on the triangular system, the outer dotted line, No. 1, being the curve obtained with aluminium-lead-tin alloys at about 800° (Part VI), and the inner dotted line that for zinc-lead-antimony alloys at 800° (Part VII). Obviously, the first five tie-lines belong to a perfectly regular curve, which, by analogy with the other two dotted curves, might be expected to follow approximately the course indicated by the middle dotted line No. 3; so that the tie-lines 8, 9, and 10 doubtless represent simply the effect of the separation of *solid* aluminium antimonide from what would otherwise be a "real" alloy, this action probably taking place partly during the period of tranquil fusion, and partly during the short time requisite to cool down the resulting compound ingot. In the case of tie-lines 6 and 7, the mixtures of metals used appear to have corresponded with ideal alloys, and the heavier alloys that were obtained did not widely differ from such as would be expressed by points on the normal critical curve; but this was not the case with the lighter alloys, where the quantities of aluminium

and antimony present relatively to the lead are abnormally increased through the formation of solid AlSb and its admixture with the fluid lighter alloy.

As regards the direction of slope of the tie-lines, it is noticeable that they all slope downwards to the left, as in the case of zinc-lead-antimony alloys. Obviously, the substitution of aluminium for zinc in these raises the critical curve, as in all other similar cases so far examined. On the other hand, the substitution of antimony for tin depresses the curve (so far as the normal portion is concerned, at any rate), just as in the case of zinc-lead-tin and zinc-bismuth-tin alloys.

Mixtures of Aluminium, Bismuth, and Antimony.

A parallel series of experiments with aluminium-bismuth-antimony alloys gave the following results as the averages from the examination of twenty-five compound ingots (fifty alloys). The analysis was made as in the case of zinc-bismuth-antimony alloys (Part VII), except that the acid filtrate from the precipitated sulphides of bismuth and antimony was precipitated with ammonia, the Al_2O_3 ultimately weighed being corrected for Fe_2O_3 and SiO_2 (p. 138).

Fig. 3 represents these values plotted on the triangular system, the dotted line No. 1 representing the corresponding results obtained with aluminium-lead-antimony alloys, and the inner dotted line, No. 2, those obtained with zinc-bismuth-antimony alloys (Part VII). Obviously, the substitution of bismuth for lead depresses the critical curve, as usual; the uppermost portion shows precisely the same irregularity in the form of a central hornlike excrescence, due to the separation of solid SbAl, as was observed with aluminium-lead-antimony alloys; whilst the lower portion of the right-hand branch shows the same kind of sharply-marked inward depression as was previously observed with zinc-bismuth-antimony alloys, due to the formation of the definite compound of bismuth and antimony, Sb_2Bi_3, aluminium (like zinc) being capable of dissolving this compound to a greater extent than mixtures of the two metals where one or the other predominates beyond this proportion.

	Calculated for Sb_2Bi_3.	Found at position of maximum depression (5th tie-line).	
Bismuth....	72·2	25·52 =	73·4
Antimony ..	27·8	9·26 =	26·6
	100·0	34·78	100·0

It is noticeable that the direction of slope of the tie-lines is the same as that with aluminium-lead-antimony alloys, downwards to the left; whereas with zinc-lead-antimony and zinc-bismuth-antimony the

No. of tie-line.	Heavier alloy.			Lighter alloy.			Excess of antimony percentage in lighter alloy over that in heavier.
	Antimony.	Bismuth.	Aluminium.	Antimony.	Bismuth.	Aluminium.	
0	0	99·72	0·28	0	2·02	97·98	0
1	0·50	98·31	1·19	1·30	4·61	94·09	+ 0·80
2	1·39	96·84	1·77	3·54	7·91	88·55	+ 2·15
3	1·25	97·22	1·53	5·57	9·65	84·78	+ 4·32
4	2·25	95·00	2·75	7·41	14·63	77·96	+ 5·16
5	3·16	93·83	3·01	9·26	25·52	65·22	+ 6·10
6	2·86	95·37	1·77	10·39	19·67	69·94	+ 7·53
7	3·35	94·10	2·53	10·81	15·48	73·71	+ 7·46
8	9·70	84·35	5·95	17·67	19·35	62·98	+ 7·97
9	17·48	70·22	12·30	29·58	22·08	48·34	+ 12·10
10	21·94	65·54	12·52	36·53	22·45	41·02	+ 14·59
11	30·40	58·65	15·86	43·55	24·59	31·86	+ 13·06
12	40·16	39·18	20·71	48·40	23·40	28·20	+ 8·24
13	46·66	29·87	23·47	50·50	23·90	25·60	+ 3·84

FIG. 3.

Sb.

Bi.   Al.

direction was reversed according as lead or bismuth was present, viz., downwards to the left in the first case, and to the right in the second.

II. "On the Photographic Arc Spectrum of Iron Meteorites." By Professor J. NORMAN LOCKYER, C.B., F.R.S. Received December 22, 1893.

(Abstract.)

This communication consists of a discussion of the photographic arc spectra of the Nejed and Obernkirchen meteorites, the wavelengths of the lines being based upon those determined by means of the photographic arc spectrum of electrolytic iron, a paper concerning which has been recently communicated to the Society. The portion of the spectrum covered by the photographs extends from K to D.

The wave-lengths, intensities, and origins of the lines in the spectra are given in tabular form.

The following general conclusions have been arrived at:—

1. The spectra of the two meteorites closely agree, both as regards the number and intensities of the lines, the slight difference in number being probably due to a difference of exposure.

2. The meteoritic spectra and the solar spectrum show considerable similarity. The iron lines in each have about the same relative intensity, thus indicating that the temperature of the iron vapour in the sun which produces the majority of the iron lines is about the same as that of the electric arc.

3. The results of the inquiry into the origin of the lines, in addition to those of iron, may be thus summarised:—

Substances certainly present.	Substances probably present.
Manganese.	Strontium.
Cobalt.	Lead.
Nickel.	Lithium.
Chromium.	Cerium.
Titanium.	Molybdenum.
Copper.	Vanadium.
Barium.	Didymium.
Calcium.	Uranium.
Sodium.	Tungsten.
Potassium.	

4. Of the few faint lines in the tables, for which no origins have been found from the Kensington maps of metallic arc spectra, the majority are apparently coincident with lines mapped by Messrs. Kayser and Runge in the iron spectrum. These do not appear in the Kensington photographs, probably on account of insufficient exposure.

5. By noting the difference in intensity of identical lines in the two spectra, a rough approximation can be made to the relative quantities of the different substances present in the meteorites. Thus it is found that the chief chemical difference between the two meteorites is that there is a preponderance of calcium in the Nejed, and of nickel, barium, and strontium in the Obernkirchen, meteorite.

III. "On the Straining of the Earth resulting from Secular Cooling." By CHARLES DAVISON, M.A., Mathematical Master at King Edward's High School, Birmingham. Communicated by Professor POYNTING, F.R.S. Received January 10, 1894.

(Abstract.)

If the coefficient of dilatation (e) and the conductivity (κ) are constant at every point within the earth, and if the temperature (V) was initially the same throughout, the depth of the surface of zero-strain after 100 million years is 2·17 miles, the total volume of the crust folded and crushed above that surface is about 184,500 cubic miles, and the mean thickness of the crushed rock spread over the whole surface of the earth is 4·95 ft. (taking $e = 0\cdot0000057$, $\kappa = 400$, $V = 7000°$ F.). The smallness of these figures has been claimed by some geologists as a new and strong argument against the contraction theory of mountain evolution.

In the present paper the problem is reconsidered on the supposition that the coefficient of dilatation is not constant, but increases with the temperature, the change in the former varying as the corresponding change in the latter. It follows, from experiments made by Fizeau, that, for a rise of one degree in temperature, the coefficient of dilatation increases on an average by about 1/888. Adopting this value, and taking the other constants as above, it is found that, after 100 million years, the depth of the surface of zero strain is 7·79 miles, the total volume of crust-folding about 6,145,000 cubic miles, and the mean thickness of the layer formed by spreading it over the whole earth 164·7 ft.

If the conductivity increases with the temperature, or if the material which composes the earth's interior be such that the conductivity and coefficient of dilatation are greater in it than in the surface rocks, or if initially the temperature increased with the depth, the figures given in the preceding paragraph must be still further increased. It follows, therefore, that calculations as to the alleged insufficiency of the contraction theory to produce mountain ranges are at present inadmissible.

IV. " Chemical Analysis of the Meteoric Stone found at Maka-
riwa, near Invercargill, New Zealand, in the year 1886."
By L. FLETCHER, M.A., F.R.S., Keeper of Minerals in the
British Museum. Received December 13, 1893.

(Abstract.)

As the preliminary investigation of the Makariwa stone had
already indicated to Professor Ulrich* the presence of mineral con-
stituents having the physical characters of olivine, enstatite, glass, a
substance resembling glass, nickel-iron, troilite, magnetite, hydrous
oxide of iron, and possibly chromite, the quantitative chemical analysis
presented difficulties, among which may be specially mentioned the
fact that one chemical element (iron) enters into the composition of
each of the above fine-grained and closely intermingled constituents.
This chemical examination I was invited to undertake by Professor
J. W. Judd, F.R.S., through whom the two fragments of the stone
sent to this country by Professor Ulrich have been generously pre-
sented to the British Museum.

The composite method adopted for the analysis was as follows :—

It was found advisable to make a preliminary separation of the
powder by means of a magnet into attracted and unattracted
material. Treatment of a portion of the attracted material with a
solution of mercuric ammonium chloride, as recommended by Dr.
Friedheim,† revealed the fact that the proportion of rust was
too large to be negligible, and indicated the necessity of a pre-
liminary reduction of the rust of the unattracted material, and of a
subsequent extraction of the reduced metal with mercuric solution ;
this prevents the unattracted oxide of iron due to rusting of the
alloy from passing into the hydrochloric acid extract with the oxide
of iron of the silicate decomposed by the acid. Accordingly, after
the sulphur and phosphorus of the unattracted material had been
determined, mercuric solution was employed both before and after
heating the material to low redness in a current of hydrogen (as
recommended by von Baumhauer), the residual unrusted and rusted
nickel-iron being thus separately removed. Analysis of the post-
reduction mercuric extract showed that there had been a small, but
appreciable, action on the silicate portion of the meteorite during the
reduction. Further, it became obvious that the troilite was largely
affected by the heating in hydrogen, and in such a way that the
greater part of the iron of that constituent, and practically all the
iron and nickel of the schreibersite, had gone into the mercuric

* ' Roy. Soc. Proc.,' 1893, vol. 53, p. 54.
† ' Sitz. Ak. Berlin,' 1888, p. 345.

solution. Hence, determinations of the sulphur and phosphorus in the mercurialised residue were made, so that the iron and nickel which had passed into the mercuric solution from the affected troilite and schreibersite might be allowed for. The mercurialised residue was next treated with hydrochloric acid, and the solution analysed; the silica was extracted from the undecomposed residue by sodium carbonate solution containing some caustic soda, and the small amounts of bases simultaneously extracted were likewise determined; the undecomposed residue itself was then separately analysed. Further, various determinations of the alkalies were made.

The microscopical examination made by Professor Ulrich having suggested no character or constituent different from those previously met with in meteoric stones, the interest of the chemical investigation was rather in the study of an analytical method than in the numerical results to be obtained. As pointed out by Dr. Friedheim, in the memoir already referred to, recent analyses of fragments of the Alfianello stone show enormous variations: they are probably in great part due to the incompleteness of the separations of the constituent minerals from each other.

As a result of the observations made in the course of the analysis of the Makariwa stone, the following points may be emphasised:—

1. It is advisable to first effect, as far as practicable, a magnetic separation of the mineral constituents: otherwise, owing to the malleability of the nickel-iron, the powdered material may be neither sufficiently fine, nor sufficiently homogeneous as a mixture. Further, without this separation, the appreciable proportion of the iron-rust may escape observation.

2. The solution of mercuric ammonium chloride, suggested by Dr. Friedheim, is very satisfactory in being without appreciable action on any other constituent than the nickel-iron, if used as directed.

3. If the attracted material be treated with acid without previous extraction by means of mercuric solution, the composition deduced for the nickel-iron may be completely wrong, owing to the solution of iron-rust simultaneously with the nickel-iron.

4. After reduction of the rust in the unattracted material by heating to low redness in hydrogen, and after subsequent treatment with the mercuric solution, no troilite or schreibersite will be left in the residue if the operations are sufficiently prolonged. There is an appreciable effect on the silicate portion during the operations.

5. The enstatite can be completely freed from olivine by three extractions with hydrochloric acid (sp. gr. 1·06) on the water-bath— probably by two.

6. The Deville-Cooke method is very advantageous for the separation of the small quantities of aluminium and chromium from the iron.

It may be added that the microscopical characters of minerals have now been so minutely investigated that, for mere determination of the mineralogical species of the constituents, the microscopic examination of a thin section of a meteorite by the petrologist is more complete and expeditious than a chemical analysis.

The following numerical results were deduced from the observations, an account of the technical details of which will appear in the 'Mineralogical Magazine':—

I. *Mineralogical Composition of the Stone.*

(*a.*) *After weathering—*

Metallic iron	1·55
Metallic nickel (cobalt)	1·08
Copper	trace
Oxide of iron (Fe₃O₄)	3·48
Olivine (including glass and substance resembling glass)	48·61
Enstatite	38·40
Troilite	5·94
Schreibersite	0·63
Chromite	0·31
	100·00

(*b.*) *Before weathering—*

Nickel-iron	5·20
Olivine	49·08
Enstatite	38·77
Troilite	6·00
Schreibersite	0·64
Chromite	0·31
	100·00

(*c*) *Ratios of constituents—*

100 parts of the silicate portion would consist of 55·87 parts of olivine and 44·13 parts of enstatite.

100 parts of the original nickel-iron would consist of 78·94 of iron and 21·06 of nickel (cobalt); the analysis of 0·1450 gram of the residual nickel-iron gave 82 per cent. of iron and 18 per cent. of nickel (cobalt).

The nickel and cobalt are in the proportion to each other of 4·7 : 1, or of 12 : 1; the former proportion was deduced from the analysis of reduced rust, the latter from analysis of the mercuric extract of the residual unrusted alloy itself, which may have a different composition.

II. *Percentage Composition of the Enstatite.*

		Oxygen.
SiO_2	54·46	28·87
MgO	22·76	
FeO	16·74	
CaO	4·17	
MnO.............	0·39	14·51
Al_2O_3	0·21	
K_2O	0·15	
Na_2O	1·12	
Li_2O	trace	

100·00

This corresponds very closely with the typical enstatitic formula $R''O \cdot SiO_2$, and shows that all the olivine had been extracted.

III. *Percentage Composition of the Olivine (including Glass and Substance resembling Glass).*

		Oxygen.
SiO_2	40·68	21·56
MgO	35·64	
FeO	22·06	
CaO	1·16	19·62
MnO	0·29	
Al_2O_3	0·17	

100·00

This corresponds approximately with the typical formula of an olivine, $2R''O \cdot SiO_2$. The deviation from the typical formula is probably chiefly due to solution of part of the finely-divided enstatite during the separation of the olivine by means of hydrochloric acid, and may partly arise from the solution of the other constituents mentioned by Professor Ulrich, " glass and a substance resembling glass."

IV. *Alkalies.*

The various determinations made of the alkalies were consistent in indicating that the alkali present is essentially soda, and that the soda is almost wholly, if not solely, present in a mineral constituent which is only slightly attacked by water, alcohol, ether, or dilute hydrochloric acid.

V. *Chemical Relationship to other Meteoric Stones.*

For the olivinic silicate, the ratio of the oxygen in combination with the iron and manganese to that in combination with the magnesium and calcium is 1 : 2·9; in this respect the Makariwa stone resembles those of Gopalpur (1 : 2·75); Mezö-Madaras and Eichstädt (1 : 2·8); Montréjeau and Pultusk (1 : 2·9); Borkut and Chantonnay (1 : 3).*

For the enstatitic silicate, the corresponding ratio is 1 : 2·7. This approximates to those of Eichstädt (1 : 2·2); Manegaum, Waconda, and Tjabé (1 : 2·3); Seres (1 : 2·4); Georgia and Montréjeau (1 : 2·5); Grosnaja (1 : 2·6); Utrecht (1 : 2·7); Ski (1 : 2·8); Borkut (1 : 3).

Of the above meteoric stones, that which stands nearest in this respect for both silicates is Montréjeau; other stones approximating to Makariwa in both ratios are Borkut, Eichstädt, Tjabé, Utrecht, and Linn County.

In the proportion of the olivine to the enstatite, there is also a close similarity: in Makariwa the proportion is 56 : 44; in Montréjeau, 54 : 46.

The proportion of nickel (18—21 per cent.) in the alloy is higher than the average, and approximates to that of Middlesbrough (23 per cent.).

Presents, February 15, 1894.

Transactions.

Cambridge, Mass.:—Harvard University. Bulletin. Vol. VII. No. 5. 8vo. *Cambridge* 1894. The University.

Copenhagen:—Danish Biological Station. Report. 1893. 8vo. *Copenhagen* 1893. The Station.

Cracow:—Académie des Sciences. Bulletin International. Décembre, 1893. 8vo. *Cracovie.* The Academy.

International:—Congrès International de Zoologie. 2ème Session, Moscou, 1892. Partie 2. 8vo. *Moscou* 1893.
Société Imp. des Amis des Sciences Naturelles, Moscow.

Kazan:—Imperial University. Scientific Notes. 1894. No. 1. [*Russian.*] 8vo. *Kazan.* The University.

Kew:—Royal Gardens. Bulletin of Miscellaneous Information. 1894. No. 86. 8vo. *London.* The Director.

London:—British Association for the Advancement of Science. Index to the Reports and Transactions from 1861 to 1890 inclusive. 8vo. *London* 1893. The Association.

* 'Die Chemische Natur der Meteoriten,' von C. F. Rammelsberg. Berlin, 1879.

Transactions (*continued*).

Linnean Society. Journal (Botany). Vol. XXX. No. 206. 8vo. *London* 1894; List. 1893-94. 8vo. *London* 1894.

The Society.

Manchester :—Geological Society. Transactions. Vol. XXII. Part 14. 8vo. *Manchester* 1894. The Society.

Literary and Philosophical Society. Memoirs and Proceedings. Vol. VIII. No. 1. 8vo. *Manchester* [1894]. The Society.

New York :—American Geographical Society. Bulletin. Vol. XXV. No. 4. Part 1. 8vo. *New York* 1893.

The Society.

Paris :—Société Mathématique. Bulletin. Tome XXI. No. 9. 8vo. *Paris;* Tables des Vingt Premiers Volumes. ` 8vo. *Paris* 1894. The Society.

Trieste :—Società Adriatica di Scienze Naturali. Bollettino. Vol. XV. 8vo. *Trieste* 1893. The Society.

Observations and Reports.

Brussels :—Observatoire Royal de Belgique. Annuaire. 1894. 8vo. *Bruxelles* 1894. The Observatory.

Washington :—Weather Bureau, U.S. Department of Agriculture. Report of the Ohio Weather and Crop Service. December, 1893. 8vo. *Norwalk, Ohio.* The Bureau.

Wellington, N.Z. :—Registrar-General's Office. Statistics of the Colony of New Zealand. 1892. Folio. *Wellington* 1893.

The Registrar-General.

Journals.

Nature Notes. Vol. V. No. 50. 8vo. *London* 1894.

Selborne Society.

Stazioni Sperimentali Agrarie Italiane. Vol. XXV. Fasc. 3—4. 8vo. *Modena* 1893. R. Stazione Agraria, Modena.

Bramwell (B.) Atlas of Clinical Medicine. Vol. I. Vol. II. Parts 1—3. 4to. *Edinburgh* 1891-93. The Author.

Simone (G. de) Della Zoofitogenia o Generazione Animale-Vegetale dei Moscherini del Caprifico. 8vo. *Andria* 1893.

The Author.

Weber (W.) Werke. Bd. IV. Theil 2. Bd. VI. 8vo. *Berlin* 1894. K. Gesellschaft der Wissenschaften, Göttingen.

February 22, 1894.

The LORD KELVIN, D.C.L., LL.D., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The Bakerian Lecture was delivered as follows:—

BAKERIAN LECTURE.—" On the Relations between the Viscosity (Internal Friction) of Liquids and their Chemical Nature." By T. E. THORPE, D.Sc., F.R.S., and J. W. RODGER, Assoc. R.C.S.   Received February 22, 1894.

(Abstract.)

The purpose of this paper is to throw light upon the relations between the viscosity of homogeneous liquids and their chemical nature. It is divided into three parts.

Part I contains a summary of the attempts which have been made, more particularly by Poiseuille, Graham, Rellstab, Guerout, Pribram and Handl, and Gartenmeister, to elucidate this question. Although it is evident from the investigations of these physicists that relationships of the kind under consideration do exist, it must be admitted that they are as yet not very precisely defined, mainly for the reason that the conditions by which truly comparable results can alone be obtained have received but scant consideration.

For example, it seems futile to expect that any definite stoichiometric relations would become evident by comparing observations taken at one and the same temperature. Practically, nothing is known of a quantitative character concerning the influence of temperature on viscosity.

From the time which a liquid takes to flow through a capillary tube under certain conditions, which are set out at length in the paper, a measure of the viscosity of the liquid can be obtained.

An apparatus was, therefore, designed on this principle which admitted of the determination in absolute measure of the viscosity, and for a temperature range extending from $0°$ up to the ordinary boiling point of the liquid examined. In this way instead of finding, as has been the usual custom, relative times of flow in the same apparatus under the same external conditions of temperature and pressure, and which

might or might not be taken as measures of a single physical magnitude of the substance, *i.e.*, its viscosity, the physical magnitude itself could be measured, and the various influences which are found to affect its value could be allowed for. The physical constants thus obtained could then be treated from the point of view of the chemist, and the comparison would then be of the same kind as that employed in connexion with other physical magnitudes.

Full details of the conditions determining the dimensions of the apparatus and of the modes of estimating these dimensions, together with the methods of conducting the observations, are given in the paper.

The corrections to be applied to the direct results are then discussed.

The question of the mathematical expression of the relation of viscosity of liquids to temperature is considered, and reasons are given for preferring the formula of Slotte—

$$\eta = c/(1+bt)^n,$$

η is here the coefficient of viscosity in dynes per square centimetre, and c, b, and n are constants varying with the liquid.

With a view of testing the conclusions set out at length in the historical section of the paper, and, in particular, of tracing the influence of homology, substitution, isomerism, and, generally speaking, of changes in the composition and constitution of chemical compounds upon viscosity, a scheme of work was arranged which involved the determination, in absolute measure, of the viscosity of some seventy liquids, at all temperatures between $0°$ (except where the liquid solidified at that temperature) and their respective boiling points.

Part II of the memoir is concerned with the origin and modes of establishing the purity of the several liquids ; it contains the details of the measurements of the viscosity coefficients, together with the data required to express the relation of viscosity coefficients to temperature by means of Slotte's formula, and tables are given showing the agreement between the observed and calculated values.

In Part III the results are discussed. In the outset the factors upon which the magnitude of the viscosity probably depends are dealt with. The influence of possible molecular aggregations, as indicated by observations of vapour densities, boiling points, and critical] densities, and, more especially, by measurements of surface energy, made by Eötvös in 1886, and more recently by Ramsay and Shields, are taken note of.

The deductions which may be made by considering the graphical representation of the results, showing the variations of viscosity coefficients with temperature, are then set forth.

For liquids which probably contain simple molecules, or for which

there is little evidence of association of molecules at any temperature, the following conclusions may be drawn :—

1. In homologous series the coefficient of viscosity is greater, the greater the molecular weight.

2. An iso-compound has always a smaller viscosity coefficient than the corresponding normal compound.

3. An allyl compound has, in general, a coefficient which is greater than that of the corresponding isopropyl compound, but less than that of the normal propyl compound.

4. Substitution of halogen for hydrogen raises the viscosity coefficient by an amount which is greater, the greater the atomic weight of the halogen; successive substitutions of hydrogen by chlorine in the same molecule bring about different increments in the viscosity coefficients.

5. In some cases, as in those of the dichlorethanes, substitution exerts a marked influence on the viscosity, and in the case of the dibromides and benzene, it may be so large that the compound of higher molecular weight has the smaller viscosity.

6. Certain liquids, which probably contain molecular complexes, do not obey these rules. Formic and acetic acids are exceptions to Rule 1. The alcohols at some temperatures, but not at all, are exceptions to Rule 2; at no temperatures do they conform to Rule 3.

7. Liquids containing molecular complexes have, in general, large values of $d\eta/dt$.

8. In both classes of liquids the behaviour of the initial members of homologous series, such as formic acid and benzene, is in some cases exceptional when compared with that of higher homologues.

As regards the influence of temperature on viscosity, it is found that the best results given by Slotte's formula are in cases where the slope of the curve varies but little with the temperature. From the mode in which the values of the constants n and b are derived, it cannot be expected that their magnitudes will be related in any simple manner to chemical nature. With the exception of certain liquids, such as water and the alcohols, which are character-ised by large temperature coefficients, and in which there is reason to expect the existence of molecular aggregates, the formula

$$\eta = c/(1 + \beta t + \gamma t^2),$$

obtained from Slotte's expression by neglecting terms in the deno-minator involving higher powers of t than t^2, gives a close agreement with the observed results, and in this formula the magnitude of β and γ are definitely related to the chemical nature of the sub-stances.

In order to obtain quantitative relationships between viscosity and

chemical nature, and to compare one group of substances with another, it is necessary to fix upon particular temperatures at which the liquids may be taken as being in comparable conditions as regards viscosity, and to compare the values of the viscosities at those temperatures.

The first comparable temperature which suggested itself was the boiling point.

A second comparable temperature was obtained by calculating values of corresponding temperatures by the method of van der Waals with such data as could be obtained.

The third basis of comparison consisted in using temperatures of equal slope, *i.e.*, temperatures at which the rate of change of the viscosity coefficient is the same for all liquids.

At each of the different conditions of comparisons, the experimental results have been expressed according to the same system, in order to show at a glance relationships between the magnitudes of the viscosity constants and the chemical nature of the substances. The liquids are arranged so that chemically related substances are grouped together. Tables are constructed which give the values of the three different magnitudes derivable from measurements of the viscosity of the substances.

1. Values of viscosity coefficients (η).
2. Values of $\eta \times$ molecular area, *i.e.*, *molecular viscosity*.
3. Values of $\eta \times$ molecular volume, *i.e.*, *molecular viscosity work*.

The coefficient η is the force in dynes which has to be exerted per unit-area of a liquid surface in order to maintain its velocity relative to that of another parallel surface at unit distance equal to unity. It seemed, however, that relations between viscosity and chemical nature would best be brought to light if, instead of adopting merely unit-areas, areas were selected upon which there might be assumed to be the same number of molecules. The *molecular viscosity* is proportional to the force exerted on a liquid molecule in order to maintain its velocity equal to unity under the unit conditions above defined. With the units chosen it is the force in dynes exerted on the molecular area in square centimetres under unit conditions. The *molecular viscosity work* may be regarded as proportional to the work spent in moving a molecule through the average distance between two adjacent molecules under unit conditions. In ordinary units it is the work in ergs required to move a surface equal to the molecular area in square centimetres through the molecular length in centimetres.

In the case of the comparison of the viscosity coefficients at the boiling point, it is found :

1. As an homologous series is ascended, in a few cases the viscosity coefficient remains practically the same, but in the greater number of series the coefficients diminish. In one series the coefficients increase ;

м 2

in the case of the alcohols the coefficients vary irregularly with ascent of the series.

2. Of corresponding compounds, the one having the highest molecular weight has in general the highest coefficient (the aliphatic acids, and to a much greater extent the alcohols, do not conform with this rule).

3. Normal propyl compounds have, as a rule, slightly higher values than allyl compounds; in the case of the alcohols, propyl compounds have much the higher value.

4. The effect of molecular weight in some cases may be more than counterbalanced by that of constitution, or of complexity.

5. The lowest members of homologous series frequently exhibit deviations from the regularity shown by higher members.

6. An iso-compound has in general a larger coefficient than a normal compound, and the differences reach their maximum in the case of the alcohols.

7. In the case of other metameric substances, branching in the atomic chain and the symmetry of the molecule influence the magnitudes of the coefficients; the ortho-position, in the case of aromatic compounds, appears to have a more marked effect on the coefficient than either the meta- or para-position. Acetone and ether have coefficients that are less than half the values given by the isomeric alcohols.

8. One of the most striking points thus brought to light is the peculiar behaviour of the alcohols, and to some extent of the acids, as contrasted with that of other liquids.

Comparisons of molecular viscosity at the boiling point show—

1. That, with the exception of the alcohols, dibromides, and the lowest members of homologous series, an increment of CH_2 in chemical composition corresponds with an increase in molecular viscosity.

2. With the above exceptions, it is also apparent that the corresponding compound having the highest molecular weight has the highest molecular viscosity: the difference in molecular viscosity between the corresponding members of two correlated series is fairly constant.

3. The relationships shown in the other tables are substantially of the same nature as those given by the viscosity coefficients.

The comparisons which give the largest deviation from regularity contain those substances which, as already shown, exhibit a peculiar behaviour, namely, the alcohols, acids, propylene dibromide, ethylene dichloride, &c.

In order to indicate how molecular viscosity at the boiling point is quantitatively connected with chemical nature, attempts were made to calculate the probable partial effects of the atoms on the molecular

viscosity. Values were also assigned to the effects of the iso-grouping of atoms, the double linkage of carbon atoms, and the ring grouping. The values thus obtained are given in the following table :—

Fundamental Viscosity Constants (molecular viscosity at the boiling point, in dynes $\times 10^4$).

Hydrogen..............................	80
Carbon................................	−98
Hydroxyl oxygen, C—O—H	196
Ether oxygen, C—O—C	35
Carbonyl oxygen, C=O	248
Sulphur, C—S—C	155
Chlorine..............................	284
Bromine (in monobromides)	420
Bromine (in dibromides)	479
Iodine	520
Iso-grouping	15
Double-linkage	113
Ring-grouping.........................	610

As regards the meaning to be attached to fundamental viscosity constants in general, the following points may be noted. Viscosity may be taken as a measure of the attractive forces in play between molecules, i.e., of intermolecular attraction. From the fact that an increment of CH_2 in chemical composition, or the substitution of an atom of chlorine, bromine, or iodine for an atom of hydrogen, brings about a definite change in the viscosity, it is evident that intermolecular attraction is really a property of the atoms forming molecules. But, besides change in molecular weight, change in the mode of grouping of the same atoms also affects the magnitude of the viscosity. The observations show that iso-compounds have values differing from those of isomeric normal compounds ; ring compounds have not the values which, by the study of straight chain compounds, they might be expected to have. Compounds containing hydroxyl oxygen give values of the viscosity differing widely from those of compounds containing carbonyl oxygen. The same atoms must, therefore, exert different effects when differently linked together. That the effects of all the atoms in the molecule are not altered by change in the mode of linkage is proved by the fact that the effect of CH_2, of iodine, of bromine, &c., is the same in normal and in iso-compounds.

In the present state of the question it is impossible to say what particular atoms are affected by change in the mode of linkage. Hence the method adopted in deducing fundamental constants is to assume that certain atoms retain the same values under all conditions,

whilst the change in the values of those atoms which are affected by the mode of linkage is, when possible, expressed either by a new constant—the value of an iso-linkage, a double linkage, &c., or by saying that a particular atom has assumed a new value, e.g., carbonyl oxygen, hydroxyl oxygen, &c. In some cases the method of calculation may lead to the result that a negative constant is ascribed to a particular atom. In deducing the values of carbon and hydrogen, for example, it is implied that in a CH_2 group and in the molecule of a paraffin the individual effect of each atom of carbon or of hydrogen is the same. The above facts, and the reasoning based upon them, show that this is not the case, and although the absolute effect exerted by each atom upon the viscosity is positive, the fundamental constant of an atom may be negative, as it may involve a constitutive effect, which at present cannot be localised in a particular region of the molecule. For these reasons fundamental constants are to be regarded as empirically ascertained magnitudes, which are merely intended to indicate how far the observed results may be represented as the sum of partial values which are the same for all substances. They have no reference to the possible behaviour of the elements when in the free state; they simply show how far definite changes in chemical nature correspond with definite changes in viscosity.

Tables are given which show the concordance between the observed molecular viscosity and those calculated by means of these constants. In the case of forty-five liquids the difference between the observed and calculated values rarely exceeds 5 per cent. In the case of the isomeric ketones and aromatic hydrocarbons, the differences are in part due to constitutive influences, which cannot at present be allowed for in obtaining the calculated values.

In a second table are given those substances for which the differences exceed this 5 per cent. limit. These may be roughly classed as unsaturated hydrocarbons, polyhalogen compounds, formic and acetic acids, benzene, water, and the alcohols.

Similar fundamental constants for molecular viscosity work at the boiling point have also been deduced. These are given in the table on p. 155.

Tables are also given showing the comparison between the observed and calculated numbers, the substances being classified into two groups, as in the case of molecular viscosity, according as the differences are less or greater than about 5 per cent.

On taking a general survey of the comparisons at the boiling point, it is evident that for the majority of the substances examined—the paraffins and their monohalogen derivatives, the sulphides, the ketones, the oxides, and most of the acids and the aromatic hydrocarbons—molecular viscosity and molecular viscosity work may be

Fundamental Viscosity Constants (molecular viscosity work at the boiling point, in ergs $\times 10^3$).

Hydrogen................................	−1·5
Carbon................................	50
Hydroxyl oxygen, C—O—H...............	102
Ether oxygen, C—O—C..................	27
Carbonyl oxygen, C=O.................	41
Sulphur, C—S—C	99
Chlorine.............................	109
Bromine (in monobromides)............	· 176
Bromine (in dibromides)	212
Iodine	233
Iso-grouping	5
Double-linkage	31
Ring-grouping........................	60

quantitatively connected with chemical nature. The remaining substances—unsaturated hydrocarbons, di- and poly-halogen compounds, formic acid, benzene, water, and the alcohols—present marked exceptions to the foregoing regularities.

As regards the comparison of the viscosity magnitudes at the corresponding temperature, it is found that, although the critical data are too unsatisfactory to warrant us in laying any particular stress on the relationships obtained under this condition of comparison, these relationships are similar to, even if less definite than, those obtained at the boiling point. For a property like viscosity, which alters so rapidly with temperature, a corresponding temperature is no better as a condition of comparison than the boiling point.

On comparing the viscosity curves of those substances which give the best physicochemical relationships at the boiling point, it was at once seen that the general shape of the curves towards the boiling point was practically the same. If tangents were drawn to the curves at points corresponding with the boiling points of the liquids, the inclinations of the tangents to the axes, that is, the *slopes* of the curves, varied but little. On the other hand, the curves for liquids such as the alcohols, or the lowest members of homologous series, which gave little indication of physicochemical relationships, had invariably a different shape; the inclinations of tangents drawn at the boiling point were markedly different from those of the majority of substances. It seemed probable, therefore, that the discrepancies were related to this difference in the value of the slopes, and that, if the temperature of comparison was chosen so as to eliminate this difference, better relationships ought to be obtained. This idea led

to the adoption of temperatures of equal slope as comparable temperatures, and, indeed, apart altogether from considerations such as the above, which refer to the particular case of viscosity, much may be said, from a theoretical point of view, in favour of employing such temperatures for physicochemical comparisons in general.

To begin with, at the temperature of equal slope, the effect of temperature upon the property examined is the same for different substances. In the case of viscosity, for instance, $d\eta/dt$, or the rate at which viscosity is being altered by the temperature, has the same value for all liquids, and this equality might be taken as sufficient justification for supposing that at temperatures of equal slope the substances, so far as viscosity is concerned, are in comparable states.

Another argument which may be advanced in favour of such a method of treatment is that the comparable temperatures are chosen by means of a study of the effect of temperature on the property actually examined. The main objection which can be urged against the boiling point as a comparable temperature, even when, as in the case of such a property as density, it gives comparatively definite stoichiometric relationships, is that these relationships may not be general. If, however, comparable temperatures be chosen, as in the case of slope by a study of the property considered, the generality of the relationships obtained can be ascertained without the study of other properties of the substances.

Comparisons were made, therefore, at temperatures at which $d\eta/dt$ is the same for the different liquids. Or, graphically, the temperatures may be defined as those corresponding with points on the viscosity curves at which tangents are equally inclined to the axes of co-ordinates. The temperatures are therefore those at which temperature is exercising the same effect on viscosity, and for shortness may be termed *temperatures of equal slope*. The temperatures were obtained by means of Slotte's formula.

It was apparent from the shape of the curves that all the liquids could not be compared at any one value of the slope, because the effect of temperature on the slope varied so much from substance to substance. In some cases—the whole of the alcohols for example—the slope at the boiling-point was considerably greater than that at 0° in the case of some of the less viscous liquids. A slope was, therefore, selected at which as many liquids as possible could be compared. Another slope was then obtained at which the outstanding liquids could be compared with as many as possible of the liquids used at the original value of the slope. The relationships between the magnitudes of the viscosities of these liquids which could be compared at the two slopes were then found to be *the same at either slope*, so that general conclusions regarding the behaviour of all the liquids could be deduced. These are as follows :—

1. Temperatures of equal slope tend to reveal much more definite relationships between the values of viscosity coefficients and the chemical nature of the substances than are obtained at the boiling point.

2. In all homologous series, with the exception of those of the alcohols, acids, and dichlorides, the effect of CH_2 on the value of the coefficient is positive, and tends to diminish as the series is ascended.

3. Of corresponding compounds the one of highest molecular weight has the highest coefficient.

4. Normal propyl compounds have slightly larger coefficients than the corresponding allyl compounds.

5. An iso-compound has invariably a larger coefficient than a normal compound.

6. In the case of other isomers the orientation of the molecule and branching of the atomic chain influence the magnitudes of the coefficients. Similar effects of constitution are also exhibited on comparing saturated and unsaturated hydrocarbons, and the variable effects produced by successive substitution of halogen for hydrogen.

7. The alcohols, and to some extent the acids, still give results which are peculiar when compared with other substances.

As regards molecular viscosity at equal slope the following conclusions may be drawn :—

1. For the great majority of the substances molecular viscosity at equal slope can be calculated from fundamental constants which express not only the partial effects of the atoms existing in the molecule, but also those due to different atomic arrangements. These are given in the accompanying table :—

Fundamental Viscosity Constants (molecular viscosity at Slope 0·0₄323, in dynes × 10⁴).

Hydrogen.................................	44·5
Carbon	31
Hydroxyl oxygen, C—O—H.................	166
Ether oxygen, C—O—C	58
Carbonyl oxygen, C=O	198
Sulphur, C—S—C..........................	246
Chlorine (in monochlorides).............	256
Chlorine (in dichlorides)...............	244
Bromine (in monobromides)	372
Bromine (in dibromides).................	361
Iodine..................................	499
Iso-grouping	−21
Double-linkage..........................	48
Ring-grouping...........................	244

The large effects which can be attributed to the ring-grouping of atoms, to the iso-linkage, to double-linkage, and to changes in the condition of oxygen in its compounds, as well as the smaller effects due to the accumulation of atoms of halogen in a molecule, render evident the quantitative influence of constitution.

2. Of the remaining substances the chlormethanes, tetrachlorethylene, ethylidene chloride and carbon bisulphide give deviations from the calculated values on account of constitutive influences not allowed for in obtaining the fundamental constants.

3. The alcohols and water exhibit no agreement with the calculated values. The mode in which deviations vary indicates, in the case of the alcohols, that the disturbing factor is related to their chemical nature.

The results obtained from the consideration of molecular viscosity work at equal slope, are of precisely the same nature as those discussed under molecular viscosity.

The fundamental constants are as follows :—

Fundamental Viscosity Constants (molecular viscosity work at Slope 0·0₄323, in ergs × 10³).

Hydrogen..............................	− 34
Carbon	148
Hydroxyl oxygen, C—O—H..............	100
Ether oxygen, C—O—C	43
Carbonyl oxygen, C=O.................	− 19
Sulphur, C—S—C	144
Chlorine (in monochlorides)	89
Chlorine (in dichlorides).............	82
Bromine (in monobromides)	151
Bromine (in dibromides)..............	148
Iodine...............................	218
Iso-grouping	− 8
Double-linkage	− 95
Ring-grouping.......................	−369

The substances which give deviations from the calculated values fall into two classes. In the first the deviations are to be attributed to chemical constitution, inasmuch as similar disturbing effects may be detected in the magnitudes of other physical properties which afford no evidence of being influenced by molecular complexity.

In the second are substances like the acids, water, and the alcohols, for which the disturbing factor is, no doubt, molecular complexity.

The question of the generality of the results obtained is next discussed. It is evident :

1. That over such temperature ranges as the observations extend the results obtained at a particular value of the slope may be regarded as general for all liquids, with the exception of the alcohols, for which the relationships vary slightly as the slope alters. A general expression connecting the viscosity coefficient with the slope is given.

2. It is further indicated, from comparisons made by the use of slopes which varied from liquid to liquid, and which were chosen according to definite systems, that in the present state of the question equal slope is the most suitable condition at which to compare the viscosities of different liquids.

With respect to the relationships existing between the magnitudes of the comparable temperatures of equal slope, it appears :—

1. That these vary in a regular way with the chemical nature of the substances, except in the case of liquids like benzene and propylene dibromide, giving viscosity curves which are abnormal when compared with those of their homologues.

2. The temperature relationships may also be regarded as general and thus independent of the value of the slope, except in the case of the alcohols, which, in this respect, as in that of viscosity at equal slope, are anomalous.

The rest of the memoir is concerned with the discussion of certain general conclusions regarding physicochemical comparisons ; and it finally deals with other possible methods of obtaining and comparing viscosity magnitudes.

Presents, February 22, 1894.

Transactions.

Adelaide :—Royal Society of South Australia. Transactions. Vol. XVII. Part. 2. 8vo. *Adelaide* 1893. The Society.

Berlin :—Gesellschaft für Erdkunde. Verhandlungen. Bd. XX. Nos. 8—10. 8vo. *Berlin* 1893. The Society.

Brisbane :—Royal Society of Queensland. Proceedings. Vol. VI. Part 1. Vol. VII. Parts 1—2. Vol. VIII. Parts 1—4. 8vo. *Brisbane* 1889-92. The Society.

Calcutta :—Asiatic Society of Bengal. Journal. Vol. LXII. Part 1. No. 3. Part 2. No. 3. Part 3. Nos. 1—3. 8vo. *Calcutta* 1893 ; Proceedings. 1893. Nos. 8—9. 8vo. *Calcutta* 1893. The Society.

Edinburgh :—Royal Society of Edinburgh. Transactions. Vol. XXXVII. Part 2. 4to. *Edinburgh* 1893 ; Proceedings. Vol. XX. Pp. 97—160. 8vo. *Edinburgh* 1893 ; List of Members. 1893. 4to. The Society.

Transactions (*continued*).

International:—Congrès Internationaux d'Anthropologie et d'Archéologie Préhistorique et de Zoologie, Moscou, 1892. Matériaux concernant les Expéditions Scientifiques, les Excursions et les Rapports sur les Questions touchant les Congrès. Partie 2. 8vo. *Moscou* 1893.

<div align="right">Société Impériale des Amis des Sciences Naturelles, &c., Moscou.</div>

London:—Anthropological Institute. Journal. Vol. XXIII. No. 3. 8vo. *London* 1894. <div align="right">The Institute.</div>

Entomological Society. Transactions. 1893. Part 5. 8vo. *London* 1894. <div align="right">The Society.</div>

London Mathematical Society. Proceedings. Vol. XXIV. Nos. 469—474. 8vo. *London* 1893. <div align="right">The Society.</div>

Odontological Society. Transactions. Vol. XXVI. No. 3. 8vo. *London* 1894. <div align="right">The Society.</div>

Royal College of Physicians. List of the Fellows, Members, Extra-Licentiates, and Licentiates. 1894. 8vo. *London.* <div align="right">The College.</div>

Santiago:—Sociedad Nacional de Minería. Boletin. Vol. V. No. 61. 4to. *Santiago de Chile* 1893. <div align="right">The Society.</div>

Stockholm:—Kongl. Vetenskaps Akademie. Öfversigt. Årg. L. No. 9. 8vo. *Stockholm* 1894. <div align="right">The Academy.</div>

Washington:—U.S. Department of Agriculture. Experiment Station Record. Vol. V. No. 4. 8vo. *Washington* 1894. <div align="right">The Department.</div>

Observations and Reports.

Calcutta:—Meteorological Department, Government of India. Monthly Weather Review. August, 1893. 4to. *Calcutta;* Meteorological Observations recorded at Seven Stations in India. August, 1893. 4to. <div align="right">The Department.</div>

London:—Royal Commission appointed to inquire into the Subject of Vaccination. Fourth Report. Folio. *London* 1893. <div align="right">Stationery Office.</div>

Norway:—Norske Gradmaalingskommission. Vandstandsobservationer. Hefte 5. 4to. *Christiana* 1893. The Commission.

Paris:—Bureau des Longitudes. Annuaire. 1894. 8vo. *Paris.* <div align="right">The Bureau.</div>

St. Petersburg:—Physikalisches Central-Observatorium. Annalen. Jahrg. 1892. 4to. *St. Petersburg* 1893. <div align="right">The Observatory.</div>

Sweden:—Sveriges Geologiska Undersökning. Afhandlingar och Uppsatser. Ser. Aa. Nos. 108—109. Ser. Ab. Nos. 13—15.

Observations and Reports (*continued*).

> Ser. Bb. No. 7. Ser. C. Nos. 112, 116—134. [With accompanying Maps.] 8vo. and 4to. *Stockholm* 1891-93.
>
> The Survey.
> Washington :—Weather Bureau, Department of Agriculture. Monthly Weather Review. November, 1893. 4to. *Washington.*
> The Bureau.

Frederick the Great. Politische Correspondenz. Bd. XX. 8vo. *Berlin* 1893. K. Akademie der Wissenschaften, Berlin.

Greig (J. A.) Den Norske Nordhavs-Expedition, 1876-78. Zoologi— Ophiuroidea. 4to. *Christiania* 1893.
Editorial Committee of the Expedition.

Rambaut (A. A.) To adjust the Polar Axis of an Equatorial Telescope for Photographic Purposes. 8vo. *London* [1894].
The Author.

" Note on some Changes in the Blood of the General Circulation consequent upon certain Inflammations of acute and local Character." By C. S. SHERRINGTON, M.D., F.R.S., Lecturer on Physiology, St. Thomas's Hospital, Professor-Superintendent of the Brown Institution, London. Received December 11, 1893,—Read December 14, 1893.

[PLATE 1.]

In result of an acute inflammatory process of even limited local extent alterations, that have been long recognised, take place in the blood of the general circulation. These alterations are (1) hyperinosis, or increased yield of fibrin ; (2) leucocytosis, or numerical increase of leucocytes.

Of all the phenomena of inflammation the most fundamental, apart from the local degeneration of the involved tissue, is, without doubt, abnormal exudation of intravascular fluid. The latter process must produce changes in the blood in general circulation, as well as in that in the vascular area locally disturbed. It is these general hæmic changes incident on local inflammation with which my experiments deal, especially with certain features of the inflammatory leucocytosis.

I. METHODS.

The inflammatory lesion I have established by trauma of one or other kind, induced generally by thermal means. When the seat chosen for the lesion has been in the limb, the procedure has been as follows.

The animal being deeply anæsthetised, the nerves to the limb have been carefully severed, in order to destroy sensation in the limb. Then the main artery to the limb (femoral or brachial) has been occluded by digital compression, and the extremity of the member immersed in water at 52° C. for five minutes. The limb has then been wiped dry, the animal allowed to recover from anæsthesia, and replaced in its stall.

The blood was examined at least once before establishment of the lesion. Afterwards a series of examinations were made, and these, with records of body-temperature and respiration, furnish the chief observations obtained from the experiments.

When the site of the lesion has been in an abdominal organ the same general plan has been followed, except that, as a rule, no nerve has been severed. Sponges steeped in 0·6 per cent. aqueous NaCl solution at 52° C. were applied for five minutes to a knuckle of intestine, brought to a small incision in the linea alba; the gut was then carefully replaced, and the wound closed, the whole performed with strict precautions for asepsis. In several instances, instead of the above plan, mechanical trauma was employed in the form of ligation of the knuckle of intestine. In several experiments where inflammation, primarily of a mucous surface, was requisite, use was made of specific chemical irritants in the form of cathartics administered by the stomach; but I have for the present endeavoured to avoid the use of chemical and bacterial irritants.

For the examination of the blood "drop" methods have been used throughout; the withdrawal of even quite small quantities of blood from the circulation induces rapid alteration in the circulating blood itself. By "drop" methods this source of error is avoided. Moreover "drop" methods have the advantage of not necessitating any binding down or tying of the animal, and it has by several authorities[*] been shown that these fixations of the animal, especially when continued over longish periods, induce of themselves severe changes in the composition of the blood. The animals employed have been the dog and cat, and occasionally the rabbit. The drop of blood required for examination has been almost always taken from the pinna of the ear.

For the counting of corpuscles I have used a selected pair of previously tested Thoma-Zeiss "counters." The instruments are guaranteed to vary in capacity by less than 1 per cent. of the capacity of each, *i.e.*, by less than 0·001 mm.. My pair showed no difference measurable under the magnification of the Zeiss Objective D. I have therefore discarded enumerations which have not tallied on the two counters within 10 per cent. I have not used the Thoma-Zeiss pipette, but one by Hawksley, containing no bead, and of a different shape from the Thoma-Zeiss pipette. Objec-

---

[*] *Cf.* especially Löwit, 'Studien zur Physiologie u. Pathologie des Blutes u. der Lymphe,' p. 9, &c.

tions to the Thoma-Zeiss pipette are, the large surface relatively to cubic content, the difficulty of drying the bead quickly enough for use in successive observations, and the presumption that leucocytes will adhere to the bead.

I have always *counted both chromocytes and leucocytes in the same film of the diluted blood, and in the same film enumerated the representatives of the various kinds of leucocytes distinguishable, e.g., finely granular, coarsely granular, large hyaline, small hyaline.* I imagine the carrying out of the enumeration of all the elements on *one and the same* film to be a point of importance. The methods of counting in which the enumeration of chromocytes is carried out in one film, that of leucocytes in a second, and the determination of the numerical proportion between varieties of leucocytes in a third and fourth, let a number of possible and probable variants into the observation which are excluded in carrying out the whole operation upon one and the same large film. Certain countings it is naturally impossible to combine in one and the same film; for instance, those dependent on the colour reactions introduced by Ehrlich cannot be combined with enumerations on a living film; but it is possible to translate the one results into the other, and to make in that way the two modes of counting yield, as it were, control observations.

For diluting the blood, I have used the following solution :—

Distilled water	300	grams.
Sodium chloride	1·2	„
Neutral potass. oxalate	1·2	„
Ehrlich's purified methyl blue	0·1	gram.

The chromocytes are not laked in it for several hours at the ordinary temperature of the room. The leucocytes of the dog, cat, and rabbit are not killed by immersion in it for several hours; they are reduced to a sluggish condition, and at the ordinary temperature of the room do not locomote over the floor of the counter. This fluid is preferable to Thoma's 0·3 per cent. acetic solution, which soon kills the leucocytes outright, and rapidly destroys much of their finer structural character. The object of the acid solution is to render invisible the chromocytes by laking them. When blood is diluted only ten times, as is usual for counting leucocytes in the Thoma-Zeiss apparatus, the number of chromocytes present tends to obscure the leucocytes. Myself, I met that difficulty in my earlier countings (although chromocytes and leucocytes were always, both of them, enumerated in one and the same film), by rendering the chromocytes, after counting them, invisible by freezing, and proceeding to count the leucocytes. The freezing was done by placing the counter on a carefully levelled freezing microtome, freezing the film for a few seconds, and then letting it thaw again. Most of the chromocytes are thus laked, and the leucocytes are most of them little altered. The difficulty arising from condensation of moisture on the cover glass is met by using the water immersion objective. It seems better, however, to dilute the blood more freely than ten times, and not to freeze the film. I have latterly always used the solution in the proportion of 49 parts to 1 part of blood. This admixture allows of the chromocytes being easily counted, the normal blood of the dog offering then about 33 chromocytes per square on the floor of the counter.

In counting leucocytes one of the most serious mishaps that can occur is for the leucocytes to cluster or "ball." It is obvious that where this has happened the enumeration is useless. The hyaline leucocytes seem less sticky than do the granular leucocytes. There is always, however, a tendency for all leucocytes to clump in this way. In the above fluid in the above proportion, I have had to reject very few observations on account of clumping. The basis obtained for numerical calculation is, of course, reduced by increase of dilution. This

I have remedied by increasing the area for enumeration on the floor of the counter. I have always counted all the leucocytes found *on the whole ruled floor-space of the two counters*, *i.e.*, not merely on the squares, but outside them, as far as the ruled lines extended. The area thus obtained was in one of the counters (Counter A) 5¾ that of the squared area. In the other counter (Counter B) it was 4⅘⅞⅞, the size of the squared area; this I have treated as 5. As basis for calculation, I have had, therefore, instead of the usually ascertained actual number of leucocytes in 0·01 mm. of blood, the actual number in 0·0215 mm. of blood, a basis more than twice as wide. The counting has been made on the Zeiss movable stage on his Stativ IV, 1, with the dry 4 mm. apochromatic objective, usually combined with ocular 8. Countings have been occasionally carried on on the warm stage (Israel's).

The amount of hæmoglobin in the blood I measure by the Gower's instrument, by the light of a Welsbach lamp reflected from a vertical sheet of white paper not otherwise illuminated.

The specific gravity of the blood is estimated by Roy's[*] method, as in the observations by Copeman and myself.[†] The specific gravity of the blood serum is also observed by Roy's method. The blood is previously centrifuged in capillary tubes. Havilland and Lloyd Jones[‡] have both employed the centrifuge for separating corpuscles from fluid in minute quantities of blood received into capillary tubes.

The exact procedure with me has been as follows. A drop of blood, as it exudes from a prick in the skin, is taken by capillarity into a fine, freshly drawn glass tube, like a vaccine tube, but longer, and bent into a U shape. The capillary U-tube is then placed with its bent end downwards into a "bucket" on the centrifuge, or in a radial slot on a vulcanite disc; the two open ends will then lie toward the centre of rotation, and in a few minutes a clear layer of serum or plasma is obtained in each limb of the tube. The specific gravity of the supernatant fluid can be readily ascertained by Roy's method. I say serum or plasma, because it is surprising how often no trace of fibrin seems to exist in the clear layer, even on standing for a long time.

The clear fluid I have often found to be absolutely cell free. I shall refer to the fluid as serum, but I suspect that in several instances it was pure plasma.

Where the temperature is recorded, the rectal temperature in degrees centigrade is meant. By respiratory rate is meant number of inspirations per minute.

II.

The varieties of hæmic leucocytes which I have attempted to distinguish are explained more fully on pp. 186—194. The nomenclature adopted is based on Wharton Jones[§] and Max Schultze.[‖]

[*] 'Journal of Physiology,' vol. 5, p. 9, 1884.
[†] 'Journal of Physiology,' vol. 9, p. 8, 1890.
[‡] 'British Medical Journal,' September 23, 1893.
[§] "The Blood Corpuscle considered in its different Phases of Development," 'Phil. Trans.,' 1846, p. 64.
[‖] 'Archiv für Mikroskopische Anatomie,' vol. 1, p. 1, 1863.

1. Finely granular leucocytes.
2. Coarsely granular leucocytes.
3. Hyaline leucocytes: *α.* Large.
   „   „   *β.* Small.

Differences between Cat's Blood and Dog's Blood.

The number of chromocytes per unit volume blood is greate in cat's blood than in dog's blood. The individual chromocytes are smaller in the former; according to Gulliver,* the average diameter in cat is 1/4404 in.; in dog, 1/3542 in. The ratio of leucocytes to chromocytes in normal cat's blood is distinctly lower than in dog's blood; this is probably a result of the greater number of the smaller chromocytes per unit volume of cat's blood.

In the blood of nearly one half of the dogs I have examined, a few nucleated chromocytes have been met with. It has been so in some instances with old dogs (in half-grown puppies they are found in numbers); in all instances the dogs were not known to be ailing; some were certainly very active and well-nourished. The nucleated chromocytes were always of the kind called normoblasts. In adult cats the blood seems to contain nucleated chromocytes less commonly, but I have met with them.

The specific gravity of the serum of cat's blood has in my experiments averaged distinctly higher than that of dog's blood.

The coarsely granular leucocyte appears rather more numerous in cat's blood than in dog's. Certain differences between the coarsely granular leucocytes in the two species will be mentioned in a short description of the leucocytes (p. 189.)

(1.) *The Seat of Acute Local Inflammation is in the Limb.*

The inflammation was induced in the extremity of the limb in the way above described.

The results on the blood will be best shown by quoting some examples.

Example.

Dog.

10.30 A.M. Temperature, 88·8°. Respiration, 20.

Sp. gr. of blood from artery in ear	1·065
Hæmoglobin value.	72
Sp. gr. of blood serum	1·025
Number of chromocytes per mm. blood	6,553,332
„ leucocytes per mm. blood	6,609
„ hyaline leucocytes per mm. blood	302
„ coarsely granular leucocytes per mm. blood	435
„ irregularly nucleate leucocytes per mm. blood.......	6,281

---

* 'Proceedings of the Zoological Society of London,' June 15, 1875

Ratio of leucocytes to chromocytes........................ 1 : 993

„   hyaline leucocytes to chromocytes............ ...... 1 : 21,844

„   coarsely granular leucocytes to chromocytes .... 1 : 15,065

„   hyaline leucocytes to total leucocytes .... 5·2 per cent.

„   coarsely granular leucocytes to total leucocytes........ 6·8   „

11—11.15 A.M.   Temperature, 38·8°.   Respiration, 20.
Lesion established in both hind legs.

12.40 P.M.   Temperature, 38°.   Respiration, 18.

Sp. gr. of blood of ear..................................... 1·078

Hæmoglobin value.. 95

Sp. gr. of blood serum.................................... 1·024

Number of chromocytes per mm. blood 8,600,000

„   leucocytes per mm. blood ....:...... 15,304

„   hyaline leucocytes per mm. blood (the small kind very
scarce) 802

„   coarsely granular leucocytes per mm. blood......... 404

„   irregularly nucleate leucocytes per mm. blood 14,400

Ratio of leucocytes to chromocytes........................ 1 : 562

„   hyaline leucocytes to chromocytes.................. 1 : 10,750

„   coarsely granular leucocytes to chromocytes........... 1 : 21,500

„   hyaline leucocytes to total leucocytes................ 5·2 per cent·

„   coarsely granular leucocytes to total leucocytes........ 2·6   „

3.15 P.M.   Temperature, 38°.   Respiration, 16.

Sp. gr. of blood from ear.................................. 1·0795

Hæmoglobin value ....·.................... 98

Sp. gr. of blood serum .... 1·0235

Number of chromocytes per mm. blood 9,175,000

„   leucocytes per mm. blood 17,913

„   hyaline leucocytes per mm. blood (small kind less
scarce relatively) 378

„   coarsely granular leucocytes per mm. blood......... 168

„   irregularly nucleate leucocytes per mm. blood 17,502

Ratio of leucocytes to chromocytes .... 1 : 512

„   hyaline leucocytes to chromocytes.................. 1 : 24,182

„   coarsely granular to chromocytes.................. 1 : 53,970

„   hyaline leucocytes to total leucocytes................ 2·2 per cent.

„   coarsely granular leucocytes to total leucocytes........ 0·9   „

5.15 P.M.   Temperature, 38°.   Respiration, 14.

Sp. gr. of blood from ear.................................. 1·081

Hæmoglobin value.. 106

Sp. gr. of blood serum.................................... 1·0235

Number of chromocytes per mm. blood 10,200,000

„   leucocytes per mm. blood 32,956

„   hyaline leucocytes per mm. blood 890

„   coarsely granular leucocytes per mm. blood .... none found.*

„   irregularly nucleate leucocytes per mm. blood 32,100

Ratio of leucocytes to chromocytes .... 1 : 309

„   hyaline leucocytes to chromocytes.................... 1 : 11,460

„   „   „   total leucocytes .... 1 : 37

---

* "None found " refers, unless otherwise stated, to search in the two counters.

12 noon next day.   Temperature, 37·8°.   Respiration, 22.

Sp. gr. of blood from ear..................................... 1·0785
Hæmoglobin value... 96
Sp. gr. of blood serum.. 1·0235
Number of chromocytes per mm. blood...................... 8,800,000
   „   leucocytes per mm. blood........................ 29,410
   „   hyaline leucocytes per mm. blood................ 1,430
· „   coarsely granular leucocytes per mm. blood...... none found.
   „   irregularly nucleate leucocytes per mm. blood... 28,110
Ratio of leucocytes to chromocytes.......................... 1 : 290
   „   hyaline leucocytes to chromocytes................. 1 : 6,153
   „   „   „   total leucocytes.............. 1 : 20·5
The smaller kind of hyaline leucocyte forms about 15 per cent. of
   all the hyaline leucocytes.

12 noon next day.   Temperature, 34°.   Respiration, 24.

Sp. gr. of blood from ear................................... 1·078
Hæmoglobin value... 91
Sp. gr. of blood serum..................................... 1·024
Number of chromocytes per mm. blood...................... 8,300,000
   „   leucocytes per mm. blood........................ 12,630
   „   hyaline leucocytes per mm. blood................ 1,280
         (Of these about 25 per cent. are the small variety.)
   „   coarsely granular per mm. blood................. none found.
   „   irregularly nucleate per mm. blood.............. 11,070
Ratio of leucocytes to chromocytes......................... 1 : 657
   „   hyaline leucocytes to chromocytes................. 1 : 6,484

Example.

Dog.
   9.30 A.M.   Temperature, 39°.   Respiration, 24.

Sp. gr. of blood taken from ear............................. 1·066
Hæmoglobin value... 69
Sp. gr. of blood serum..................................... 1·0245
Number of chromocytes in mm. blood....................... 8,126,600
   „   leucocytes in mm. blood......................... 7,500
   „   hyaline leucocytes in mm. blood................. 1,100
   „   coarsely granular in mm. blood.................. 417
   „   irregularly nucleate leucocytes per mm. blood... 6,330
Ratio of leucocytes to chromocytes......................... 1 : 1,083
   „   hyaline leucocytes to chromocytes................. 1 : 7,387
   „   coarsely granular leucocytes to chromocytes....... 1 : 19,480
   „   hyaline leucocytes to total leucocytes............ 1 : 6·8
   „   coarsely granular leucocytes to total leucocytes.. 1 : 18

10.30 —10.45 A.M.   Lesion established in one limb only.

11.15 A.M.   Temperature, 38·6°.   Respiration, 20.

Sp. gr. of blood taken from ear............................. 1·072
Hæmoglobin value... 78
Sp. gr. of blood serum..................................... 1·025
Number of chromocytes in mm. blood....................... 8,910,000
   „   leucocytes in mm. blood......................... 6,670
   „   hyaline leucocytes in mm. blood................. 1,060
   „   coarsely granular leucocytes in mm. blood....... 330

Number of irregularly nucleate leucocytes in mm. blood 5,590
Ratio of leucocytes to chromocytes .... 1 : 1,186
    „   hyaline leucocytes to chromocytes .... 1 : 8,800
    „   coarsely granular leucocytes to chromocytes .... 1 : 27.000
    „   hyaline leucocytes to total leucocytes............... 1 : 6·2
    .,   coarsely granular leucocytes to total leucocytes .... 1 : 20

12.45 P.M.   Temperature, 39·2°.   Respiration, 24.
Sp. gr. of blood from ear .... 1·071
Hæmoglobin value.. 76
Sp. gr. of blood serum .... 1·025
Number of chromocytes in mm. blood 8,440,000
    „   leucocytes in mm. blood........................ 18,166
    „   hyaline leucocytes.............................. 1,140
    „   coarsely granular leucocytes in mm. blood.......... 174
    „   irregularly nucleate in mm. blood 1,200
Ratio of leucocytes to chromocytes .... 1 : 639
    „   coarsely granular leucocytes to chromocytes .... 1 : 48,506
    „   hyaline leucocytes to total leucocytes .... 1 : 11
    „   coarsely granular leucocytes to total leucocytes........ 1 : 79

3.15 P.M.   Temperature, 40·2°.   Respiration, 28.
Sp. gr. of blood from ear..................................... 1·0725
Hæmoglobin value... 85
Sp. gr. of blood serum....................................... 1·0245
Number of chromocytes in mm. blood 8,626,000
    „   leucocytes in mm. blood 28,833
    „   hyaline leucocytes in mm. blood 980
    „   coarsely granular leucocytes in mm. blood.......... 152
    „   irregularly nucleate leucocytes in mm. blood 27,800
Ratio of leucocytes to chromocytes........................... 1 : 299
    „   coarsely granular leucocytes to chromocytes .... 1 : 56,750
    „   hyaline leucocytes to total leucocytes .... 1 : 29
    „   coarsely granular leucocytes to total leucocytes........ 1 : 173

6 P.M.   Temperature, 39·4°.   Respiration, 25.
Sp. gr. of blood from ear .... 1·072
Hæmoglobin value... 84
Sp. gr. of blood serum .... 1·023
Number of chromocytes in mm. blood 8,561,000
    „   leucocytes in mm. blood 29,583
    „   hyaline leucocytes in mm. blood.................. 1,200
    „   coarsely granular in mm. blood .... none found in the counters.
    „   irregularly nucleate in mm. blood 28,200
Ratio of leucocytes to chromocytes........................... 1 : 289
    „   hyaline leucocytes to total leucocytes .... 1 : 24

3 P.M. next day.   Temperature, 38°·6.   Respiration, 20.
Sp. gr. of blood from ear .... 1·073
Hæmoglobin value... 85
Sp. gr. of blood serum .... 1·0235
Number of chromocytes in mm. blood 9,142,000
    „   leucocytes in mm. blood 32,330

Number of hyaline leucocytes in mm. blood 1,060

„ coarsely granular in mm. blood .... none found
in count r.

„ irregularly nucleate in mm. blood 31,100

Ratio of leucocytes to chromocytes......................... 1 : 283

„ hyaline to total leucocytes .... 1 : 31

„ coarsely granular to total leucocytes .... 1 : 850

Example.

Cat.

10 A.M. Temperature, 38°·6. Respiration, 26.

Sp. gr. of blood from ear .... 1·0535

Hæmoglobin value.. 44

Sp. gr. of blood serum .... 1·0305

Number of chromocytes in mm. blood 7,160,000

„ leucocytes in mm. blood 14,232

„ hyaline leucocytes in mm. blood 3,581

„ coarsely granular leucocytes in mm. blood.......... 1,395

„ irregularly nucleate leucocytes in mm. blood 13,380

Ratio of leucocytes to chromocytes........................ 1 : 504

„ hyaline leucocytes to chromocytes .... 1 : 1984

„ coarsely granular leucocytes to chromocytes .... 1 : 5114

„ hyaline to total leucocytes........................ 1 : 4

„ coarsely granular to total leucocytes .... 1 : 10

10.30—10.45 A.M. Lesion established in one leg.

11.50 A.M. Temperature, 38·2°. Respiration, 30.

Sp. gr. of blood from ear .... 1·059

Hæmoglobin value.. 52

Sp. gr. of blood serum .... 1·0295

Number of chromocytes in mm. blood 9,520,000

„ leucocytes in mm. blood 26,140

„ hyaline leucocytes in mm. blood 2,790

„ coarsely granular leucocytes in mm. blood.......... 930

„ irregularly nucleate leucocytes in mm. blood........ 23,280

Ratio of leucocytes to chromocytes .... 1 : 364

„ hyaline leucocytes to chromocytes .... 1 : 3412

„ coarsely granular leucocytes to chromocytes .... 1 : 10236

„ hyaline to total leucocytes........................ 1 : 9·4

„ coarsely granular to total leucocytes .... 1 : 28

5.15 P.M. Temperature, 39°·3. Respiration, 37.

Sp. gr. of blood from ear .... 1·0575

Hæmoglobin value.. 51

Sp. gr. of blood serum .... 1·0275

Number of chromocytes in mm. blood 9,160,000

„ leucocytes in mm. blood 32,420

„ hyaline leucocytes in mm. blood 1,618

„ coarsely granular leucocytes in mm. blood.......... 47

„ irregularly nucleate leucocytes in mm. blood........ 30,690

Ratio of leucocytes to chromocytes .... 1 : 282

„ hyaline leucocytes to chromocytes .... 1 : 5654

„ coarsely granular leucocytes to chromocytes.......... 1 : 194893

„ hyaline to total leucocytes........................ 1 : 20

„ coarsely granular to total leucocytes .... 1 : 697

6.30 P.M.   Temperature, 39°·2.   Respiration, 35.

Sp. gr. of blood from ear	1·058
Hæmoglobin value.....................................	51
Sp. gr. of blood serum	1·0275
Number of chromocytes in mm. blood	9,140,000
„ leucocytes in mm. blood	34,100
„ hyaline leucocytes in mm. blood..................	1,840

"   coarsely granular leucocytes in mm. blood. None found in the counters, and none in cover-glass films, nor in counting 10,000 leucocytes from the leucocyte layer in a centrifuged specimen; but one of typical normal appearance seen in examining specimens from the leucocyte layer of the centrifuged blood.

Number of irregularly nucleate leucocytes in mm. blood.......	32,150
Ratio of leucocytes to chromocytes.......................	1 : 268
„ hyaline leucocytes to chromocytes	1 : 4967
„ hyaline leucocytes to total leucocytes...............	1 : 18

Under the conditions of experiment the changes in the blood generally circulating were as follows :—

1. The specific gravity of the blood was increased.

2. The specific gravity of the serum was slightly lessened or remained not obviously altered.

3. The hæmoglobin content of the unit volume of blood was increased.

4. The number of chromocytes in the unit volume of blood was increased.

5. The numerical ratio of leucocytes to chromocytes in the unit volume of blood was always increased, sometimes after a preliminary decrease of the ratio.

6. The number of leucocytes in the unit volume of blood was at first slightly diminished and then increased; much later there was sometimes a fall to below normal.

7. The numerical ratio of coarsely granular leucocytes to chromocytes in the unit volume of blood was diminished.

8. The number of coarsely granular leucocytes in the unit volume of blood was diminished.

9. The numerical ratio of coarsely granular to the rest of the leucocytes was diminished.

10. The numerical ratio of finely granular to the rest of the leucocytes was greatly increased after a certain time.

11. The number of hyaline leucocytes in the unit volume of blood became less.

12. Hæmoglobin in solution appeared in the plasma of the blood, and of the lymph in the thoracic duct, and of the exudation fluid in the limb.

13. There seemed to be a certain small number of nucleated

chromocytes added to the blood of general circulation, but whether this was always the case I am not certain.

14. The rapidity of clotting of the blood was increased, and the lymph also clotted well.

(2.) *The Seat of the Local Inflammation is in the Abdominal Cavity.*

The inflammation was induced as above described in a tract of the small intestine. The following are examples of the experiments :—

Example.

Dog.

9.35 A.M. Temperature, 38°·5. Respiration, 23.

Sp. gr. of blood from ear	1·0515
Hæmoglobin value.......................................	47
Sp. gr. of blood serum..................................	1·023
Number of chromocytes in mm. blood...................	4,575,000
„ leucocytes in mm. blood..........................	7,750
„ hyaline leucocytes (large) in mm. blood...........	780
„ „ „ (small) in mm. blood............	282
„ coarsely granular leucocytes in mm. blood..........	1,010
„ irregularly nucleate leucocytes in mm. blood.......	5,630
Ratio of leucocytes to chromocytes....................	1 : 590
„ hyaline leucocytes to chromocytes.................	1 : 4,480
„ coarsely granular leucocytes to chromocytes.......	1 : 4,604
„ hyaline to total leucocytes......................	1 : 7·3
„ coarsely granular to total leucocytes.............	1 : 7·7

10.20 A.M. Piece of jejunum sponged.

11.15 A.M. Temperature, 38°. Respiration, 19.

Sp. gr. of blood from ear..............................	1·055
Hæmoglobin value......................................	60
Sp. gr. of blood serum	1·0225
Number of chromocytes in mm. blood...................	6,750,000
„ leucocytes in mm. blood.........................	6,690
„ hyaline leucocytes in mm. blood................	1,148
„ coarsely granular leucocytes in mm. blood.........	438
„ irregularly nucleate leucocytes in mm. blood.......	5,160
Ratio of leucocytes to chromocytes.....................	1 : 1,009
„ hyaline leucocytes to chromocytes.................	1 : 5,869
„ coarsely granular leucocytes to chromocytes........	1 : 15,340
„ hyaline to total leucocytes......................	1 : 5·9
„ coarsely granular to total leucocytes.............	1 : 13

1.15 P.M. Temperature, 38°·6. Respiration, 22.

Sp. gr. of blood from ear..............................	1,058
Hæmoglobin value.....................................	66
Sp. gr. of blood serum.................................	1·0225
Number of chromocytes in mm. blood..................	7,990,000
„ leucocytes in mm. blood	14,522
„ hyaline leucocytes in mm. blood	1,320

(About 25 per cent. of these are the small kind).

Number of coarsely granular leucocytes in mm. blood............ 370
   „   irregularly nucleate leucocytes in mm. blood 13,100
Ratio of leucocytes to chromocytes........................... 1 : 552
   „   hyaline leucocytes to chromocytes.................... 1 : 6,063
   „   coarsely granular leucocytes to chromocytes........... 1 : 21,594
   „   hyaline leucocytes to total leucocytes................ 1 : 11
   „   coarsely granular leucocytes to total leucocytes .... 1 : 39

3.45 P.M.   Temperature, 38°·2.   Respiration, 20.
Sp. gr. of blood from ear.................................... 1·060
Hæmoglobin value.. 70
Sp. gr. of blood serum...................................... 1·0225
Number of chromocytes in mm. blood 8,010,000
   „   leucocytes in mm. blood 32,067
   „   hyaline leucocytes in mm. blood.................... 764
   „   coarsely granular leucocytes in mm. blood.......... 260
   „   irregularly nucleate leucocytes in mm. blood........ 31,200
Ratio of leucocytes to chromocytes.......................... 1 : 250
   „   hyaline leucocytes to chromocytes.................... 1 : 10,540
   „   coarsely granular leucocytes to chromocytes.......... 1 : 30,808
   „   hyaline leucocytes to total leucocytes................ 1 : 42
   „   coarsely granular leucocytes to total leucocytes .... 1 : 123

5.45 P.M.   Temperature, 38°·2.   Respiration, 20.
Sp. gr. of blood from ear .... 1·060
Hæmoglobin value... 71
Sp. gr. of blood serum .... 1·0225
Number of chromocytes in mm. blood 8,040,000
   „   leucocytes in mm. blood 43,565
   „   hyaline leucocytes in mm. blood.................... 854
   „   coarsely granular leucocytes in mm. blood.......... none found in the counters.
   „   irregularly nucleate leucocytes in mm. blood........ 42,600
Ratio of leucocytes to chromocytes.......................... 1 : 184
   „   hyaline leucocytes to chromocytes................... 1 : 9,468
   „   hyaline leucocytes to total leucocytes............... 1 : 51
   „   coarsely granular leucocytes to total leucocytes must
have been very low.   No coarsely granular were found in the
"counter" nor in two cover-glass preparations, but one
example was found in a film from the leucocyte layer of a
sample of centrifuged blood.

7.30 P.M.   Temperature, 38°·3.   Respiration, 20.
Sp. gr. of blood from ear.................................... 1·0595
Hæmoglobin value.. 70
Sp. gr. of blood serum .... 1·0225
Number of chromocytes in mm. blood........................ 7,785,000
   „   leucocytes in mm. blood 55,304
   „   hyaline leucocytes in mm. blood 922
   „   coarsely granular leucocytes in mm. blood .... none found.
   ,   irregularly nucleate leucocytes in mm. blood........ 54,320
Ratio of leucocytes to chromocytes.......................... 1 : 140
   „   hyaline leucocytes to chromocytes................... 1 : 8,462
   „   hyaline leucocytes to total leucocytes............... 1 : 60

Next day. Noon. Temperature, 38°. Respiration, 19.

Sp. gr. of blood from ear .... 1·058
Hæmoglobin value.. 64
Sp. gr. of blood serum...................................... between
                                                          1·022 and
                                                          1·0225
Number of chromocytes in mm. blood....................... 7,450,000
   „   leucocytes in mm. blood......................... 30,400
   „   hyaline leucocytes in mm. blood................. 760
   „   coarsely granular leucocytes in mm. blood......... none found.
   „   irregularly nucleate leucocytes in mm. blood 29,700
Ratio of leucocytes to chromocytes .... 1 : 245
   „   hyaline leucocytes to chromocytes.................. 1 : 9,802
   „   hyaline leucocytes to total leucocytes.............. 1 : 43
In the examination of cover-glass films two coarsely granular cells were found after much search, but 1,000 leucocytes were counted without meeting one.

2.30 P.M. Temperature, 38°·4. Respiration, 18.

Sp. gr. of blood from ear................................... 1·058
Hæmoglobin value 62
Sp. gr. of blood serum...................................... 1·0223
Number of chromocytes in mm. blood....................... 7,380,000
   „   leucocytes in mm. blood......................... 33,000
   „   hyaline leucocytes in mm. blood................. 650
   „   coarsely granular leucocytes in mm. blood......... none found.
   „   irregularly nucleate leucocytes in mm. blood 32,300
Ratio of leucocytes to chromocytes .... 1 : 224
   „   hyaline leucocytes to chromocytes.................. 1 : 11,354
   „   hyaline leucocytes to total leucocytes.............. 1 : 50
No coarsely granular leucocytes met with at all.

6 P.M. Temperature, 39°. Respiration, 18.

Sp. gr. of blood from ear................................... 1·060
Hæmoglobin value.. 67
Sp. gr. of blood serum...................................... 1·0223
Number of chromocytes in mm. blood 7,800,000
   „   leucocytes in mm. blood......................... 46,600
   „   hyaline leucocytes in mm. blood................. 775
   „   coarsely granular leucocytes in mm. blood......... none found.
   „   irregularly nucleate leucocytes in mm. blood 45,800
Ratio of leucocytes to chromocytes .... 1 : 168
   „   hyaline leucocytes to chromocytes.................. 1 : 10,060
   „   hyaline leucocytes to total leucocytes .... 1 : 59·8

Noon, next day. Temperature, 38°·6. Respiration, 18.

Sp. gr. of blood from ear................................... 1·056
Hæmoglobin value... 52
Sp. gr. of blood serum..................................... 1·0223
Number of chromocytes in mm. blood....................... 4,860,000
   „   leucocytes in mm. blood......................... 31,480
   „   hyaline leucocytes in mm. blood 787
   „   coarsely granular leucocytes in mm. blood......... none found.
   „   irregularly nucleate leucocytes in mm. blood 30,300

Ratio of leucocytes to chromocytes........................... 1 : 154
„   hyaline leucocytes to chromocytes.................... 1 : 6,152
„   hyaline leucocytes to total leucocytes................. 1 : 40

Example.

Cat.

6.30 P.M.   Temperature, 38°·6.

Sp. gr. of blood from ear .... 1·049
Hæmoglobin value...................................... 51
Sp. gr. of blood serum.................................. 1·027
Number of chromocytes in mm. blood 6,040,000
„   leucocytes in mm. blood.......................... 10,610
„   hyaline leucocytes in mm. blood 1,913
„   coarsely granular leucocytes in mm. blood 1,044
„   irregularly nucleate leucocytes in mm. blood 8,600
Ratio of leucocytes to chromocytes........................ 1 : 570
,   hyaline to total leucocytes........................ 1 : 5·5
„   coarsely granular leucocytes to total leucocytes...... 1 : 10

7 P.M.   Piece of ileum sponged.

7.40 P.M.

Sp. gr. of blood from ear .... 1·052
Hæmoglobin value...................................... 54
Sp. gr. of blood serum.................................. 1·0265

9.30 A.M.   Temperature, 38°·8.   Respiration, 40.

Sp. gr. of blood.......·................................ 1·059
Hæmoglobin value...................................... 60
Sp. gr. of blood serum.................................. 1·026

One coarsely granular leucocyte met in counting through 2,000 leucocytes in
cover-glass preparations.   The films, both fresh and dried, show obvious but
not extremely severe leucocytosis.

Under these conditions of experiment the changes in the blood of
the general circulation resembled in their main features the results
observed in the experiments of series (I).   I will not therefore
recapitulate the results.   I will merely add that the addition of
nucleated chromoblasts to the blood seemed less uncertain in these
experiments than in the experiments on the limb.

A modified form of the experiment consists in simply ligating the
knuckle of intestine, and returning it with aseptic precautions into
the peritoneal cavity.   This modification, although the same main
changes in the blood were as before brought about, did not give quite
the same sequence of events.   I quote examples.

Example.

Dog.

9 P.M.   Was fed at noon.   Temperature, 39°.   Respiration, 22.

Sp. gr. of blood from ear .... 1·058
Hæmoglobin value 50
Sp. gr. of blood serum (slightly milky) .... 1·0275
Number of chromocytes in mm. blood 2,502,000
„   leucocytes in mm. blood 6,280

Number of hyaline leucocytes in mm. blood 1,740

   „   coarsely granular leucocytes in mm. blood 180

   „   irregularly nucleate leucocytes in mm. blood 4,500

Ratio of leucocytes to chromocytes........................... 1 : 400

   „   hyaline leucocytes to chromocytes .... 1 : 1,438

   „   coarsely granular leucocytes to chromocytes .... 1 : 13,900

   „   hyaline leucocytes to total leucocytes.............. 1 : 3·6

   „   coarsely granular leucocytes to total leucocytes .... 1 : 34

9.30 P.M. Ligature placed on jejunum.

9.30 A.M. Temperature, 38°·4. Respiration, 32.

Sp. gr. of blood from ear .... 1·069

Hæmoglobin value 74

Sp. gr. of blood serum (not milky) .... 1·0270

Number of chromocytes in mm. blood 6,960,000

   „   leucocytes in mm. blood 16.700

   „   hyaline leucocytes in mm. blood 560

   „   coarsely granular leucocytes in mm. blood.......... none found.

   „   irregularly nucleate leucocytes in mm. blood....... 16,120

Ratio of leucocytes to chromocytes......................... 1 : 417

   „   hyaline leucocytes to chromocytes .... 1 : 12,428

   „   hyaline leucocytes to total leucocytes .... 1 : 30

12.45 P.M. Temperature, 38°. Respiration, 28.

Sp. gr. of blood from ear .... 1·0705

Hæmoglobin value 77

Sp. gr. of blood serum .... 1·028·

Number of chromocytes in mm. blood 6,980,000

   „   leucocytes in mm. blood 8,700

   „   hyaline leucocytes in mm. blood 390

   „   coarsely granular leucocytes in mm. blood.......... none found.

   „   irregularly nucleate leucocytes in mm. blood 8,280

Ratio of leucocytes to chromocytes .... 1 : 802

   „   hyaline leucocytes to chromocytes .... 1 : 17,900

   „   hyaline leucocytes to total leucocytes .... 1 : 22

3.30 P.M. Temperature, 33°. Respiration, 20.

Sp. gr. of blood from ear .... 1·074

Hæmoglobin value..................................... 83

Sp. gr. of blood serum .... 1·029

Number of chromocytes in mm. blood 8,293,000

   „   leucocytes in mm. blood 4,868

   „   hyaline leucocytes in mm. blood 540

   „   ·coarsely granular leucocytes in mm. blood.......... none found.

   „   irregularly nucleate leucocytes in mm. blood....... 4,300

Ratio of leucocytes to chromocytes......................... 1 : 1,703

   „   hyaline leucocytes to chromocytes.................. 1 : 15,360

   „   hyaline leucocytes to total leucocytes.............. 1 : 9

6.15 P.M. Temperature, 30°·2. Respiration, 17.

Sp. gr. of blood from ear .... 1·072

Hæmoglobin value..................................... 80

Sp. gr. of blood serum.................................. 1·0295

Number of chromocytes in mm. blood 7,100,000

   „   leucocytes in mm. blood 2,610

Number of hyaline leucocytes in mm. blood 650
" coarsely granular leucocytes in mm. blood.......... none found.
" irregular nucleate leucocytes in mm. blood 1,900
Ratio of leucocytes to chromocytes............................ 1 : 2,730
" hyaline leucocytes to chromocytes.................... 1 : 10,923
" hyaline leucocytes to total leucocytes................. 1 : 4

Example.

Dog.

12.45 P.M.   Temperature, 38·4°.   Respiration, 22.

Sp. gr. of blood from ear..... .... 1·059
Hæmoglobin value.. 55
Sp. gr. of blood serum (no molecular base) .... 1·0265
Number of chromocytes in mm. blood 5,800,000
" leucocytes in mm. blood 15,900
" hyaline leucocytes in mm. blood.................. 8,200
" coarsely granular leucocytes in mm. blood 1,600
" irregularly nucleate leucocytes in mm. blood 11,000
Ratio of leucocytes to chromocytes .... 1 : 368
" hyaline leucocytes to chromocytes .... 1 : 1,812
" coarsely granular leucocytes to chromocytes .... 1 : 3,625
" hyaline leucocytes to total leucocytes .... 1 : 5
" coarsely granular leucocytes to total leucocytes ...... 1 : 10

1.15 P.M.   Jejunum ligated.

1.40 P.M.   Temperature, 38·2°.   Respiration, 22.

Sp. gr. of blood from ear .... 1·059 .
Hæmoglobin value.. 55
Sp. gr. of blood serum .... 1·0265
Number of chromocytes in mm. blood 5,815,000
" leucocytes in mm. blood 15,600
" hyaline leucocytes in mm. blood.................. 8,280
" coarsely granular leucocytes in mm. blood.......... 1,540
" irregularly nucleate leucocytes in mm. blood 11,400
Ratio of leucocytes to chromocytes........................ 1 : 372
" hyaline leucocytes to chromocytes .... 1 : 1,762
" coarsely granular leucocytes to chromocytes .... 1 : 3,776
" hyaline leucocytes to total leucocytes................ 1 : 4·7
" coarsely granular leucocytes to total leucocytes........ 1 : 10

3.40 P.M.   Temperature, 38·4°.   Respiration, 22.

Sp. gr. of blood from ear .... 1·059

4.30 P.M.   Temperature, 38·7°.   Respiration, 22.

Sp. gr. of blood from ear .... 1·059
Hæmoglobin value... 56
Sp. gr. of blood serum .... 1·0255
Number of chromocytes in mm. blood 5,850,000
" leucocytes in mm. blood 15,820
" hyaline leucocytes in mm. blood.................. 6,270
(more than 50 per cent. are the " small " variety.)
" coarsely granular leucocytes in mm. blood.......... 700
" irregularly nucleate leucocytes in mm. blood .... 10,400.
Ratio of leucocytes to chromocytes........................ 1 : 389

Ratio of hyaline leucocytes to chromocytes .... 1 : 1,110

    „   coarsely granular leucocytes to chromocytes .... 1 : 8,357

    „   hyaline to total leucocytes .... 1 : 3

    „   coarsely granular leucocytes to total leucocytes .... 1 : 22·5

6.30 P.M. Temperature, 39°. Respiration, 22.

From examination in stained films the nucleated red blood cor-
puscles are not so numerous; and the proportion of hyaline
leucocytes to total leucocytes is lower, *i.e.*................... 1 : 4·5

8.30 P.M. Temperature, 38·6°. Respiration, 26.

Sp. gr. of blood from ear................................ 1·0605

Hæmoglobin value...................................... 65

Sp. gr. of blood serum.................................. 1·0255

Number of chromocytes in mm. blood 6,150,000

    „   leucocytes in mm. blood 34,350

    „   hyaline leucocytes in mm. blood 1,720

    „   coarsely granular leucocytes in mm. blood.......... 108

    „   irregularly nucleate leucocytes in mm. blood 32,600

Ratio of leucocytes to chromocytes......................... 1 : 179

    „   hyaline leucocytes to chromocytes.................. 1 : 3,578

    „   coarsely granular leucocytes to chromocytes .... 1 : 56,944

    „   hyaline leucocytes to total leucocytes............... 1 : 20·6

    „   coarsely granular leucocytes to total leucocytes........ 1 : 318

10.30 A.M. Temperature, 38°. Respiration, 24.

Sp. gr. of blood from ear .... 1·067

Hæmoglobin value...................................... 74

Sp. gr. of blood serum.................................. 1·0253

Number of chromocytes in mm. blood 8,175,000

    „   leucocytes in mm. blood 16,700

    „   hyaline leucocytes in mm. blood 1,850

    „   coarsely granular leucocytes in mm. blood.......... none found
in counter.

    „   irregularly nucleate leucocytes in mm. blood 14,800

Ratio of leucocytes to chromocytes......................... 1 : 489

    „   hyaline leucocytes to chromocytes.................. 1 : 4,418

    „   hyaline leucocytes to total leucocytes............... 1 : 9

    „   coarsely granular leucocytes to total leucocytes; as
judged by counting cover-glass preparations, the pro-
portion was about .... 1 : 650

Example.

Dog.

6.30 P.M. Temperature, 38·5°. Respiration, 22.

Sp. gr. of blood from ear................................ 1·059

Hæmoglobin value...................................... 55

Sp. gr. of blood serum.................................. 1·024

Number of chromocytes in mm. blood 5,913,300

    „   leucocytes in mm. blood 12,610

    „   hyaline leucocytes in mm. blood 2,250

    „   coarsely granular leucocytes in mm. blood.......... 790

    „   irregularly nucleate leucocytes in mm. blood 10,300

Ratio of leucocytes to chromocytes......................... 1 : 468

    „   hyaline leucocytes to chromocytes.................. 1 : 2,628

Ratio of coarsely granular leucocytes to chromocytes .... 1 : 7,485
„   hyaline leucocytes to total leucocytes .... 1 : 5·8
„   coarsely granular leucocytes to total leucocytes .... 1 : 16

7 P.M.   Ligation of piece of ileum.

8.45 A.M.   Temperature, 39·2°.   Respiration, 28.

Sp. gr. of blood from ear................................... 1·072
Hæmoglobin value.. 72
Sp. gr. of blood serum...................................... 1·025
Number of chromocytes in mm. blood........................ 7,966,000
„   leucocytes in mm. blood 29,600
„   hyaline leucocytes in mm. blood.................. 1,233
„   coarsely granular leucocytes in mm. blood......... none seen.
„   irregularly nucleate leucocytes in mm. blood........ 28,300
Ratio of leucocytes to chromocytes........................... 1 : 269
„   hyaline leucocytes to chromocytes... .... 1 : 6,476
„   hyaline leucocytes to total leucocytes .... 1 : 24

12.30 P.M.   Temperature, 38·2°.   Respiration, 25.

Sp. gr. of blood from ear.................................... 1·0735
Hæmoglobin value.. 78
Sp. gr. of blood serum...................................... 1·0255
Number of chromocytes in mm. blood 8,540,000
„   leucocytes in mm. blood 21,820
„   hyaline leucocytes in mm. blood 910
„   coarsely granular leucocytes in mm. blood.......... none found in the counters.
„   irregularly nucleate leucocytes in mm. blood........ 20,760
Ratio of leucocytes to chromocytes........................... 1 : 380
„   hyaline leucocytes to chromocytes .... 1 : 9,490
„   hyaline leucocytes to total leucocytes................ 1 : 24·5

3.30 P.M.   Temperature, 39·2°.   Respiration, 32.

Sp. gr. of blood from ear .... 1·073
Hæmoglobin value.. 81
Sp. gr. of blood serum .... 1·025
Number of chromocytes in mm. blood 8,520 000
„   leucocytes in mm. blood........................... 23,043
„   hyaline leucocytes in mm. blood 1,210
„   coarsely granular leucocytes in mm. blood.......... none found.
„   irregularly nucleate leucocytes in mm. blood 21,700
Ratio of leucocytes to chromocytes........................... 1 : 370
„   hyaline leucocytes to chromocytes .... 1 : 7,100
„   hyaline leucocytes to total leucocytes............... 1 : 19

5.45 P.M.   Temperature, 39·6°.   Respiration, 42.

Sp. gr. of blood from ear .... 1·073
Hæmoglobin value.. 82
Sp. gr. of blood serum .... 1·025
Number of chromocytes in mm. blood 8,490,000
„   leucocytes in mm. blood 21,000
„   hyaline leucocytes in mm. blood 1,060
„   coarsely granular leucocytes in mm. blood.......... none found.
„   irregularly nucleate leucocytes in mm. blood 19,900

Ratio of leucocytes to chromocytes........................ 1 : 404
„   hyaline leucocytes to chromocytes .... 1 : 8,480
„   hyaline leucocytes to total leucocytes.............. 1 : 20

(3.) *The Inflammation is located in the Gastro-intestinal Mucous Membrane.*

The. inflammation was induced from the internal surface of the bowel in the manner above described. The following will serve as an example of. the effects upon the blood :—

Example.

Cat.

10 A.M. Temperature, 39°. Respiration, 30.

Sp. gr. of blood from ear.................................... 1·053
Hæmoglobin value.. 41
Sp. gr. of blood serum..................................... 1·0285
Number of chromocytes in mm. blood 6,970,000
    „   leucocytes in mm. blood..................... 7,210
    „   coarsely granular leucocytes in mm. blood......... 1,115
Ratio of leucocytes to chromocytes.......................... 1 : 968
    „   coarsely granular leucocytes to chromocytes .... 1 : 6.335
    „   coarsely granular leucocytes to total leucocytes........ 1 : 6·4

11 A.M. 0·3 gram. calomel and 12 grams magnes. sulphate is given by mouth.

11.45 A.M. Temperature, 39°. Respiration, 32.

Sp. gr. of blood from ear................................... 1·0535
Hæmoglobin value 41
Sp. gr. of blood serum..................................... 1·0285
Number of chromocytes in mm. blood...................... 7,200,000
    „   leucocytes in mm. blood 6,920
    „   coarsely granular leucocytes in mm. blood.......... 845
Ratio of leucocytes to chromocytes.......................... 1 : 1,040
    „   coarsely granular leucocytes to chromocytes .... 1 : 8,520
    „   coarsely granular leucocytes to total leucocytes ...... 1 : 8·2
              (Hyaline leucocytes are rather numerous.)

12.45 P.M. Temperature, 38·6°. Respiration, 32.

Sp. gr. of blood from ear.................................. 1·0535
Hæmoglobin value.. 42
Sp. gr. of blood serum .... 1·0285
Number of chromocytes in mm. blood 7,340,000
    „   leucocytes in mm. blood.......................... 7,200
    „   coarsely granular leucocytes in mm. blood 780
Ratio of leucocytes to chromocytes.......................... 1 : 1,019
    „   coarsely granular leucocytes to chromocytes .... 1 : 9,410
    „   coarsely granular leucocytes to total leucocytes ...... 1 : 9·2
              (Hyaline leucocytes are rather numerous.)

3.15 P.M. Temperature, 38·4°. Respiration, 30.

Sp. gr. of blood from ear .... 1·0545
Hæmoglobin value.. 45
Sp. gr. of blood serum..................................... 1·0285
Number of chromocytes in mm. blood 7,460,000

Number of leucocytes in mm. blood 18,535
   „   coarsely granular leucocytes in mm. blood.......... 420
Ratio of leucocytes to chromocytes......................... 1 : 552
   „   coarsely granular leucocytes to chromocytes .... 1 : 17,760
   „   coarsely granular leucocytes to total leucocytes ...... 1 : 32·2

4.45 P.M. Temperature, 38·6°. Respiration, 32.

Sp. gr. of blood from ear................................... 1·065
Hæmoglobin value.. 46
Sp. gr. of blood serum..................................... 1·0285
Number of chromocytes in mm. blood 7,488,000
   „   leucocytes in mm. blood 14,700
   „   coarsely granular leucocytes in mm. blood...   One example found in the two counters together; several examples found in fresh and stained films.
Ratio of leucocytes to chromocytes .... 1 : 508

9 P.M. Temperature, 38·5°. Respiration, 30.

Sp. gr. of blood from ear .... 1·0545
Hæmoglobin value... 44
Sp. gr. of blood serum..................................... 1·0285
Number of chromocytes in mm. blood 7,200,000
   „   leucocytes in mm. blood 12,200
   „   coarsely granular leucocytes in mm. blood.......... 93
Ratio of leucocytes to chromocytes......................... 1 : 590

12 noon next day.

Sp. gr. of blood from ear................................... 1·053
(Plenty of coarsely granular leucocytes in blood, but not enumerated.)

The results in this series have followed in their broad features those of the previous. The difference from those seems one of degree rather than of kind.

Heidenhain[*] has observed that in the intestinal mucous membrane of the dog the number of cells with oxyphil granulation is increased by a purgative. He leaves it open whether his cells are the same as the oxyphil cells of the blood, and Ehrlich could not give a definite opinion on the point. A notable feature in my experiments, of this series as of the others, has been the great numerical reduction of the oxyphil (a-granulation, coarsely granular) leucocytes in the circulating blood. I believe that a similar though much less marked diminution of these cells follows the ingestion of a full meal, and also that abstinence from food causes in the blood a higher percentage of the cell (*vide infra*, p. 205).

---

[*] " Beiträge zur Histologie u. Physiologie der Dünndarmschleimhaut," 'Arch. f. Gesammte Physiologie,' vol. 43, Supplem. Heft.

III. Remarks on the Hæmic Changes observed.

In this note I propose to remark briefly on the significance to be attached to the above hæmic changes.

(I.) *The Apoplasmia of the Blood.*

The measurements shew that consequent upon an acute local inflammation the circulating blood becomes inspissated in the sense that it loses some of its plasma, while its chromocytes do not escape, or at least not in direct proportion to the loss of plasma. There results, therefore, an *apoplasmia* of the blood, referable, doubtless, to increased exudation through the vascular membrane in the inflamed area. The amount of fluid lost to the circulation by the vascular leakage at the *locus læsionis* is thus shown to be not equalised by increased entrance of lymph into the circulation, *viâ* thoracic duct, &c. The local tumor itself consists partly of fluid exudation, whence it is obvious that not all the actual fluid exuded is returned forthwith by the lymph drainage system. It is conceivable that the loss of fluid from the blood, threatening as it must, an upset of various mechanical arrangements in the circulation, would be remedied at once or very soon by call upon the tissue lymph of various other regions, especially as Heidenhain has shown that such a call can be made by chemical means appealing through the circulation. The above observations negative this idea. The plasma of the blood as regards quantity is neither maintained nor speedily re-established. The facts show that the call on the lymph of other parts, if made, does not at least suffice to speedily restore to the blood its normal quantity of fluid. Nor is the phenomenon simply a case of lost time between the escape of the fluid from the circulation and its return again into the circulation; it persists for too considerable a period. In one experiment the blood for more than sixty hours was apoplasmic to the extent that its specific gravity remained heightened 0·021 (water 1·000) above normal, while the specific gravity of its serum (plasma) was not heightened at all, indeed was 0·002 less than at outset of experiment. Nor need it be extreme in order to be long-lasting, as the following exemplifies :—

Dog, young; in good condition.

    3 P.M.   Fed at noon, chiefly lean meat.

        Sp. gr. of blood from ear .... 1·054

         ,,   ,, serum from ear .... 1·023

   Two days later.   3.15 P.M.   Temperature, 39°.   Respiration, 20.

      Not fed to day, in view of surgical operation.

        Sp. gr. of blood from ear .... 1·054

         ,,   ,, serum from ear .... 1·023

Halstead's operation of intestinal anastomosis then performed with full antiseptic precautions and under complete anæsthesia, by Messrs. Ballance and Edmunds.

4.30 (after operation).

Sp. gr. of blood from ear	1·062
„ „ serum from ear..	1·023

(or a little less).

3 p.m. Temperature, 39·2°. Respiration, 30. Took a little milk this morning.

Sp. gr. of blood from ear	1·060
„ „ serum from ear......................................	1·023

Next day, noon. Temperature, 39·8°. Respiration, 20.

Sp. gr. of blood from ear	1·059
„ „ serum from ear	1·023

Next day, noon. Temperature, 39·8°. Respiration, 20.

Sp. gr. of blood from ear	1·0585
„ „ serum from ear	1·023

Next day, noon. Temperature, 39·5°. Respiration, 20.

Sp. gr. of blood from ear.	1·0565
„ „ serum from ear......................................	1·023

Next day, noon. Temperature, 39·4°. Respiration, 20.

Sp. gr. of blood from ear	1·055
„ „ serum from ear....................................	1·023

Although never extreme in degree, the apoplasmia of the blood here lasted through five days, in consequence of a carefully-conducted surgical operation accompanied by no untoward event, and soon ending favourably.
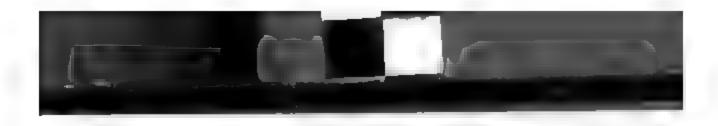
The degree of apoplasmia appears to depend in some measure upon the extent of the vascular area involved in the inflammation. For example, when both feet are involved in the lesion the apoplasmia is more severe than in experiments affecting one foot only.

Such an apoplasmia must notably increase the friction-coefficient of the blood.

Whether apoplasmia of the blood is an accompaniment in appreciable degree of all extensive local inflammation I cannot yet say. It has occurred as yet, without exception, in all my experiments, excluding three performed on the pleural cavity of the cat. The particular features of these exceptional experiments are fairly exhibited by the following example :—

Example.

Cat.

9.30 a.m. Temperature, 39°. Respiration, 30.

Sp. gr. of blood from ear.......................................	1·055
Hæmoglobin value......................................	46
Sp. gr. of blood serum......................................	1·049
Number of chromocytes in mm. blood	7,260,000
„ leucocytes in mm. blood	17,210

Number of hyaline leucocytes in mm. blood 2,760
    „   coarsely granular leucocytes in mm. blood............. 1,080

11.45 A.M. Temperature and respiration as before.
Sp. gr. of blood and serum as before.
Hæmoglobin value estimated at 47.
Number of chromocytes in mm. blood 7,450,000
    „   leucocytes in mm. blood 18,960
    „   hyaline leucocytes in mm. blood 2,700
    „   coarsely granular leucocytes in mm. blood......... 1,110

11.45—12 noon. Lesion established in right pleural cavity.

1 P.M. Temperature, 38·4°. Respiration, 40.
Sp. gr. of blood from ear.................................... 1·0548.
Hæmoglobin value... 45.
Sp. gr. of blood serum...................................... 1·029.
Number of chromocytes in mm. blood 7,100,000
    „   leucocytes in mm. blood.......................... 39,120
    „   hyaline leucocytes in mm. blood.................. 2,600
    „   coarsely granular leucocytes in mm. blood......... 610

2.30 P.M. Temperature, 37·2°. Respiration, 32.
Sp. gr. of blood from ear.................................... 1·0545
Hæmoglobin value... 46
Sp. gr. of blood serum .... 1·0285
Number of chromocytes in mm. blood. 7,500,000
    „   leucocytes in mm. blood 44,410
    „   hyaline leucocytes in mm. blood 2,415
    „   coarsely granular leucocytes in mm. blood......... 585

6.30 P.M. Temperature, 39·2°. Respiration, 34.
Sp. gr. of blood... 1·0495
Hæmoglobin value... 41
Sp. gr. of blood serum .... 1·028
Number of chromocytes in mm. blood 6,840,000
    „   leucocytes in mm. blood 46,560
    „   hyaline leucocytes in mm. blood 2,580
    „   coarsely granular leucocytes in mm. blood......... 128

Autopsy made at 7 P.M. revealed no hæmorrhage; I suspected the fall in the specific gravity might be due to hæmorrhage, and so performed autopsy at once to see the seat of it. There was a not very copious exudation into the pleural cavity; the pleural surface showed patches of inflammatory cells, but among these not many coarsely granular were found in my examination of them.

It is noticeable that, although the apoplasmia of the blood was here absent, there was, nevertheless, a great reduction in the number of coarsely granular leucocytes, not merely relatively to the rest of the leucocytes, but absolutely per unit volume of blood.

In the experiments with the ligation of a piece of intestine and mesentery, the apoplasmia developed later than in the other series. Copeman and myself[*] have noticed that in the rabbit the operation

* *Loc. cit.*, and 'Journ. of Physiol.,' vol. 14, p. 52.

of ligation of the vessels of the spleen, and various other forms of experimental interference with the contents of the abdominal cavity, including even the simple opening of the cavity by an incision through the linea alba, are all followed by increase in the specific gravity of the blood. In these cases there occurred increase in the specific gravity usually detectible in thirty minutes or less from the completion of the operation. I was therefore somewhat surprised to meet so long a latent period for the reaction in the case of the ligation of the intestine or mesentery of the dog. But in the rabbit interference with the abdomen so disturbs the normal respiration (in rabbits respiration is almost entirely abdominal) that complications arise which are far more considerable than in the dog; *e.g.*, in the rabbit the blood pressure often exhibits under these conditions a considerable temporary depression, and the respiratory rate is very greatly hurried. W. Hunter[*] has observed in this animal an increase of specific gravity of the blood to follow interperitoneal transfusion. By Copeman and myself it was suggested that this inspissation of the blood is a concomitant, or even a symptom, of "abdominal shock." Subsequent observations by Mr. Grünbaum and by myself, but especially by Professor Roy and Dr. Cobbett, have confirmed its association with abdominal operations, but I would now extend its scope to a large number of other inflammatory lesions.

(II.) *Changes in the Total Number of the Leucocytes.*

That the number of leucocytes per unit volume of circulating blood is increased in many cases of acute local inflammation is a fact established by the researches of numerous observers. Some of the most recent and detailed observations on this point are by v. Limbeck[†] and by Rieder.[‡] They supply careful measurements of the degree of this "inflammatory leucocytosis." With a number of their observations my own are fully in accord. In two respects, however, our observations do not agree.

V. Limbeck states that leucocytosis always commences prior to the occurrence of any inflammatory exudation; the exudation is a result of the leucocytosis; to my mind his observations do not prove the fact. Certainly, from a number of my experiments, I should conclude rather the reverse, because the blood became obviously apoplasmic prior to any increase of the number of leucocytes in it.

Löwit,[§] in discussing Limbeck's and Rieder's observations, remarks

---

[*] 'Journ of Physiol.,' vol. 11, p. 115.

[†] 'Arch. f. Heilkunde,' vol. 10, p. 392, 1890.

[‡] 'Beiträge z. Kenntniss d. Leukocytose,' Leipzig, 1892. Rieder gives a very complete review of previous observations and opinions on " inflammatory leucocytosis;" I will not, therefore, recapitulate them here.

[§] *Op. cit.*

that, although the fact is not mentioned by them nor obtainable from their measurements, he would expect a diminution in the number of leucocytes in the circulating blood to precede the leucocytosis. I have a number of observations which demonstrate the accuracy of this supposition by Löwit. It seems the rule for inflammatory leucocytosis to be preceded by a *leucocytopenia* (Löwit's term). This preliminary leucocytopenia of the blood is the more remarkable when, instead of the number of leucocytes per unit volume of blood, the numerical ratio of leucocytes to chromocytes is studied. If the total number of leucocytes remained the same there would, as a result of the apoplasmia at this time, appear to be an increased number of them per unit volume of blood.

The *degree* of leucocytosis which occurred in the experiments was often very considerable. The number of leucocytes per unit volume of blood was in some instances increased sevenfold. A small part only of such an increase as this can be accounted for by the co-existing degree of apoplasmia of the blood. The highest ratio of leucocytes to chromocytes observed in my experiments has been 1 : 136, a proportion corresponding very closely with the highest observed in Löwit's[*] experiments, dealing with another form of leucocytosis, viz., that following intravenous injection of albumoses, &c. But the ratio 1 : 136 was observed in the dog, and is not nearly so abnormal a ratio as the ratio 1 : 140 observed in one of the experiments on the pleural cavity of the cat. Löwit experimented on rabbits, so that my ratios are not strictly comparable with his. The largest number of leucocytes met with per c. millimeter of blood has been in my experiments 55,000, the number at the outset of the particular experiment being 7,750.

The statement by v. Limbeck,[†] supported by Gottlieb Pick,[‡] that inflammatory leucocytosis does not appear in inflammations accompanied by slight exudation, but accompanies those causing marked exudation, has not been found to hold good in my experiments, e.g., in case of inflammation in pleural cavity hardly any exudation but marked leucocytosis.

Frequently the leucocytosis is followed by a final leucocytopenic phase (*cf.* Example on page 175). This does not always occur, but it is occasionally very marked. I have only seen it happen when the temperature has fallen below normal, and the *exitus lethalis* is not far off. In one instance the leucocytes fell to less than 2000 per c. millimeter.

---

[*] *Op. cit.*
[†] 'Zeitschrift für Heilkunde,' vol. 10, p. 392, 1890.
[‡] 'Prager Med. Wochensch.,' 24, p. 303, 1890.

(III). *Disturbance of the numerical Ratios normal between the various kinds of Hæmic Leucocytes.*

Before attempting to consider the nature of the upset produced in the ratios normal between the various sets of leucocytes in the blood, it seems necessary to give some characteristics of the different sorts of hæmic leucocytes I have endeavoured to distinguish. The confused condition of the terminology applied to the subject has led of late more than once to the misapprehension of an observer's descriptions. This I would hope to avoid by prefacing my summary with a short account of the varieties of hæmic leucocytes which I have studied.

I have for the present confined the observations requiring the sorting of the leucocytes to experiments on the dog and cat. I wish it to be understood that, except where distinctly otherwise stated, this brief description is applied to the blood of those two species.

The classification followed has been based on that by Wharton Jones,[*] who was the first to discriminate varieties of white blood-corpuscles in the blood, the " finely granular" and the " coarsely granular." Some years later Rindfleisch[†] and then Max Schultze[‡] corroborated Wharton Jones' separation of the two kinds of cell, and through the work of the last authority the distinction became widely known. M. Schultze noted besides the above certain other "smallest" and "small " kinds of leucocytes. These I have followed him in keeping apart from the " finely granular " of Wharton Jones; them, together with certain of the large leucocytes, I put into a class recognised by all recent observers as scarcely at all granular, and therefore conveniently termed "hyaline"(M. Foster).[§]

A. *The Finely Granular Leucocyte.*

Large or medium in size, rarely small. Nucleus almost always obscured when the living cell is spheroid and unstained, but obvious when the cell is spread and crawling, or when half dead or tinged with nuclear dyes; the nucleus is usually polymorphous or polymerous, the lobes of it usually (almost invariably) united by bonds of chromatin. The irregularity of the nucleus is not a sign of reproduction nor of degeneration. It is, as Arnold[||] first suggested, and a number of later observers (Korschelt,[¶] Dekhuysen,[**] Gulland,[††]

---

[*] *Op. cit.*

[†] 'Pathologische Histologie,' 1861.

[‡] *Op. cit.*

[§] ' Text-book of Physiology,' Part I, p. 47, Edition 6.

[||] ' Archiv f. Mikroskopische Anatomie,' vol. 30, p. 226, 1887.

[¶] ' Zool. Jahrb., Abtheilung f. Anat. u. Ontogenie der Thiere,' vol. 4, 1889.

[**] ' Verhandlungen d. Anatom. Gesellschaft,' 1890.

[††] ' Lab. Rep. Roy. Coll. Phys., Edin.,' vol. 3, 1891.

M. Heidenhain[*]) succeed in proving, a sign and result of the amœboid activity of the cell. If the cell is allowed to quiet slowly down before it is killed, I have shown[†] that the nucleus then very usually returns to spheroidal form. Of course the cell body becomes spheroidal much sooner than the nucleus. In the slowly killed cell the nucleus usually becomes excentric in situation as well as spherical in shape. It is also especially liable to smear. In the counting solution the nucleus of this cell does not tinge so readily as does that of the hyaline leucocyte. Under certain circumstances, when kept for a number of hours *in vitro*, the nucleus of this leucocyte frequently presents a curious appearance I have not found described. The appearance is shown in figs. 6 and 7 (Plate 1). A number of portions of the nucleus are set in a wreath-like manner around the approximate centre of the cell. I have never observed this arrangement in the nucleus of the coarsely granular or hyaline leucocyte.

Cell body: finely granular. The granulation of the cell body has been called "neutrophil" by Ehrlich,[‡] Rieder,[§] &c. In the cat, under the prolonged action of aqueous methyl blue solutions, some granules, especially in the neighbourhood of the nucleus, take on a bright rose tint, and ultimately a considerable amount of rose-coloured substance in rounded masses, some of large size, appears in the cell. But the cell is much altered when this happens, and a good deal of plasmoschisis has gone on. With less departure from the normal a good deal at least of the granulation of this cell can by pushing eosin or rubin be coloured by these acid dyes; Kanthack and Hardy consider them, strictly speaking, oxyphil.

This cell is amœboid. I have previously pointed out[‖] that at low (16° C.) temperatures, it appears to be more amœboid than is the coarsely granular leucocyte. If kept for an hour or so in hanging drop at 42° C. this cell shows well the "*excroissances sarcodiques*" of Dujardin, that, as Ranvier[¶] has pointed out, are not to be confused with pseudopodia. Besides the quaint fixed finely granular excrescences there are protruded from the cell at a slightly lower temperature, quickly rising, clearer, vesicular-looking processes; these are thrust out in succession from various points of the periphery, one falling as a later rises. They lead to no locomotion of the cell. I mention them here because I have never seen the coarsely granular leucocyte or the hyaline leucocytes produce either of these excrescences, although under the same conditions, and in the same

---

[*] 'Kern u. Protoplasma,' Leipzig, 1892.

[†] 'Proc. Internat. Congress of Physiologists,' Liège, 1892.

[‡] 'Arch. f. d. Physiologie,' 1879; 'Zeitsch. f. klin. Medicin,' 1880; later papers

[§] *Op. cit.*

[‖] *Loc. cit.*

[¶] 'Traité Technique d'Histologie,' p. 156.

drop or film.   They therefore seem to me to help toward distinction between these kinds of leucocytes.

The cell can ingest particles, even hours and days after its removal from the body.   In oxalated blood these cells can often be seen with crystals inside them as well as adherent to them.   Rarely I have seen them contain a chromocyte.   Both crystals and chromocytes, when contained in the leucocytes, lie usually in obvious vacuoles.   I have occasionally seen in some of these cells fresh from the circulation some sparse small vacuoles, but they are quite uncommon in blood freshly drawn.   On the other hand after some hours, or better, one or two days *in vitro*, the cell frequently becomes riddled with small vacuoles (see figs. 2 and 3, Plate 1), so as even to resemble a flake of froth.   The nucleus is then hard to discover in the fresh cell, but on staining with basic dyes becomes at once obvious, and is then found to be no longer markedly polymerous.   The cell in this frothed condition is still amœboid, although not *very* actively, so far as I have seen.   On the warm stage it however travels fairly in this condition.   In a great number of the vacuoles fine particles can be seen, and these show that the vacuoles contain fluid, for the particles inside them exhibit Brownian movement.   Most of the vacuoles are spherical and small, some are large, as these are for the most part oval in outline.   In a number of the vacuoles *no* particles are visible.

The granules in the normal cell never, so far as I have seen, exhibit Brownian movement, but, when the cell is dead or dying, Brownian movement often affects its granules in a most marked degree, the cell body acquiring a shimmering appearance from the dancing of the granules.   This is doubtless due to lowered vitality, or perhaps lethal acidification of the cell giving its protoplasm over to imbibition of the aqueous surrounding.   Brownian movement of the granules of a leucocyte is, in my experience, one of the signs that the cell is nearly dead, and I have been interested to find it present in many of the cells of certain exudation fluids and pus, although invariably absent from the leucocytes of normal blood and lymph.

In these samples of pus leucocytes with spherical excentrically set nuclei occur, and the nuclei have an especial tendency to smear, just as in leucocytes which have slowly died *in vitro* (see fig. 4, Plate 1).

By irrigation of such weakened cells with various saline solutions that affect the normal leucocyte but little and leave it still actively amœboid, the cell body, and very often the nucleus as well, can be burst with an explosive discharge of the cell contents, the nucleus remaining as a shrunken film attached to a fragment of cell-body.

The finely granular leucocyte forms in the dog and cat about 70—90 per cent. of the hæmic leucocytes.   The vast majority of the finely granular are always, without doubt, those designated "neutrophil" by Ehrlich and his pupils; generally, I believe all of them

are. But among the finely granular there may be sometimes included the scanty basophil cells which are so rare as hardly really to be considered normal hæmic leucocytes. It must be remembered that Howell[*] and Gulland[†] have shown that in its earliest history the blood is devoid of all leucocytes. Essentially all the hæmic leucocytes are therefore vagrants wandering through blood as through the other tissues; thus it becomes difficult to set a sharp line between leucocytes normally hæmic and leucocytes only abnormally hæmic. Ehrlich includes the basophil cell as an occasional hæmic leucocyte. Basophil cells I have seen in the blood of an emaciated dog which was undergoing treatment by thyroid injections after thyroidectomy. That subvariety of basophil cells termed by Ehrlich "mastzellen," I have never met with in normal mammalian blood, but I have found them sparsely in the blood of patients dying in the reaction stage of Asiatic cholera,[‡] and at that time the inflamed submucosa and mucosa of the intestine I found often contain large numbers of these cells.

B. *The Coarsely Granular Leucocyte.*

This is among the largest of the leucocytes.

Nucleus is usually somewhat less deeply stained by nuclear dyes than the nucleus of the finely granular leucocyte; is often reniform, often irregular, and appearances intermediate between the reniform and completely irregular are common. The nucleus is always more or less obvious even when the living cell is spheroid because of absence of the characteristic granulation in its region.

Cell-body, in its greater part, contains a number of granules, more or less regularly arranged. The granules are highly refracting (especially in the cat, but much less so in the horse); the granules vary in size considerably in the same individual cell, but usually the largest is not more than thrice the size of the smallest. The shape of the granules is usually in the rabbit and dog spherical, in the cat cylindroid, in the horse roughly cuboid, but in the cat and horse many spheroid granules are often present. The average size of the cell is about the same in these three types, but the cylindroid granule of the cat is larger than the spheroid of the dog, and the cuboid granule of the horse is much larger (diameter about 2μ—4μ) than the cylindroid of the cat. In the normal cell the granules never exhibit Brownian movement, but in abnormal conditions Brownian movement sets the particles dancing freely. Under imbibition the granules usually lie trembling in the surface-sheet of the cell-body, but some-

---

[*] "The Life History of the Formed Elements of the Blood," 'Journ. Morph.,' vol. 4, p. 1, 1890.

[†] *Op. cit.*

[‡] 'Roy. Soc. Proc.,' 1886.

times they are withdrawn in a mass to the neighbourhood of the nucleus which is often excentric in the cell. It is possible, with care, when the granules are dancing at the surface of the cell, to so hold the cell between object slide and cover-slip that the dancing of the granules at the upper and under poles of the cell is arrested while the dancing in the equatorial region is unhindered. This proves, I think, not only that the granules are then very close to the surface of the cell, but that they lie not free under a cell membrane as Ranvier[*] suggests, but actually in a thin cortical layer of the cell.

As to the nature of the substance composing these granules, the idea put forward by A. Schmidt,[†] that it is closely allied to hæmoglobin, has by Pouchet[‡] and Hayem[§] been pushed so far as for them to consider the granules to be hæmoglobin and pieces of broken chromocytes. That it is not actually hæmoglobin is proved by the absence of colour from it. Ehrlich and Schwarze[||] have also found it does not give the staining reactions of the chromocytes. The granules tinge yellow over osmic vapour, but various reactions show that they are not fat. They contain a certain amount of water (Ehrlich and Schwarze); they are not soluble in alcohol or ether. In the dried corpuscles they melt (?) and run together, but at a very high temperature only (Ehrlich). As the water is driven off from them by slow heat they display a greater and greater affinity for acid stains (Schwarze). In the living cell they, in rabbit's blood, became deeply tinted (to a maroon colour) on irrigation with dilute Ehrlich-Biondi stain. In the fresh condition in the cat's blood, mixed with dilute aqueous methyl blue, it has often appeared to me, when using powerful systems, that each granule is coated with a thin film of substance which becomes blue-violet with this basic dye, and also will stain with acid fuchsin, a film, in fact, of amphophil substance. I find the granule is soluble in acetic acid, but not in distilled water. It appears to give the ammoniomolybdate reaction used to reveal phosphorus by Lilienfeld and Monti[¶]. The granulation of the finely granular leucocyte does not yield this reaction, though the cell-body of the hyaline leucocyte does usually give a faint reaction. The granules of the coarsely granular leucocyte yield the reaction readily without previous treatment to liberate the phosphorus. The granules

* *Op. cit.*, p. 168.

† 'Arch. f. d. Gesammte Physiologie,' vol. 9, p. 353.

‡ 'Journ. de l'Anat. et de la Physiologie,' 1880.

§ 'Du Sang,' Paris, 1889.

|| *Op. cit.*

¶ 'Verhandlungen der Physiologischen Gesellschaft zu Berlin,' Sitzung am Juni, 1892. Professor Halliburton, who has had considerable experience of the microscopical application of this test for phosphorus, has been so kind as to look over some of my preparations, and he endorses the opinion that the reaction is given faintly but distinctly by the coarse oxyphil granule.

of the cell give a deeper yellow than does the nucleus itself. If, as Rénaut[*] concluded, the granules are albuminous, perhaps they are of the nature of *nucleo-albumin*. Ranvier[†] has suggested that they are similar to the yolk-granules in ova, but I find those granules for by far the most part basophil.

In the description appended by Stricker to his well-known " Photogramm eines farblosen Blutkörpchen "[‡] (a coarsely-granular leucocyte of Proteus), he states that the particles sometimes show branching processes, which occasionally unite forming a network of which he sees evidence in his photogram. The granules are always really absolutely discrete, as shown in the photogram appended (Plate 1, fig. 1).

The number of granules per cell varies considerably. In the dog and cat it averages between 30 and 60; in the latter animal I have counted 78 granules and 97 granules in individual cells. In the horse the number is smaller, usually 12—20, but the granules are much larger (up to 4μ) approaching in size the huge mucin granules discovered by Reid[§] in the slime glands of *Myxine*.

In the dog I observe four morphological varieties of this leucocyte, detectable chiefly by the granulation.

1. The typical large cell, the body packed with granules, 30—60 in number.

2. The cell contains, instead of granules of fairly uniform size, one or two large, highly refracting masses, with a scanty number of the usual granules: I have found the larger masses oxyphil, and reacting to the Lilienfeld-Monti method like the usual granules.

3. The cell contains, in addition to the highly refracting granules, a few somewhat smaller rounded granules that appear in the fresh and unstained condition indistinguishable from spherical vacuoles, because the substance they contain hardly refracts more than the cell plasma. These also are oxyphil, like the highly refracting granules, and sometimes are amphophil.

4. The cell is quite small; contains a simple vesicular nucleus; the nucleus is rather large in proportion to the cell body. In the latter are coarse, highly refracting oxyphil granules, and these are distributed throughout. Dekhuysen has recently pointed out similar cells in amphibian blood. He looks upon them as the young form of the coarsely granular leucocyte; but he points out that, if I understand him rightly, the granules are amphophil, not oxyphil. In this connexion we must remember that Ehrlich has himself pointed out that the granules of his typical oxyphil cell are sometimes amphophil.

Varieties 2, 3, and 4 are, in my experience, uncommon in the blood ; when 2 does occur it seems usual for the examples of it to be fairly numerous in the blood of the animal at the time; but in most dog's blood it is not to be found at all.

[*] 'Archives de Physiologie Normale et Pathologique,' vol. 13, p. 649, 1881.
[†] *Loc. cit.*
[‡] 'Arbeit. a. dem Path. Instit. zu Wien,' 1890.
[§] "Mucin Granules of Myxine," 'Journ. Physiol.,' vol. 14, p. 340, 1893.

In cat's blood I would note three varieties of the cell.

1. The typical large cell, with its cell body packed with large cylindroid grains.

2. A cell resembling in all respects the former, except that the granules are not of the same highly refracting quality, and are generally smaller. These granules are oxyphil, like the typical ones. Variety 2 is not so frequent as 1, but it not unfrequently forms 10 per cent. of all the coarsely granular leucocytes.

3. A variety, small, and like 4 of the dog, but with granules tending to be cylindroid, instead of spheroid.

The coarsely granular leucocyte is amœboid. Myself, from what I have seen of it on the warm stage, I should incline with Lavdowski,[*] to consider it the most actively amœboid of all hæmic leucocytes, were it not for two difficulties. 1. At and below the ordinary temperature of the room, the cell is usually less actively amœboid than the finely granular leucocyte. 2. As a rule, when fixed immediately after withdrawal from the circulation the nucleus is less distorted from a regular figure than is that of the majority of the finely granular leucocytes, it is very usually of a simple horse-shoe shape; now the degree of irregularity of form of the nucleus may be taken as a rough index of the amœboid activity of the cell at the time of fixation.

I have never, either in freshly drawn blood or in blood kept for a time *in vitro*, seen an unmistakable vacuole in the coarsely granular leucocyte. This stands in striking contradistinction to one's experience of the finely granular leucocyte. Related to this absence of vacuolation appears the fact that a number of observers, including Metschnikoff,[†] admit the want of evidence that the coarsely granular hæmic leucocyte is phagocytic. In my own preparations, when, after being fed with bacteria *in vitro*, the great majority of hæmic leucocytes have ingested the bacteria (and other particles besides), the coarsely granular leucocytes have not contained any.

I think there is little doubt that, as Müller[‡] says, this coarsely granular cell is Ehrlich's cell with α-granulation—Ehrlich's true oxyphil cell—the only question is whether his amphophil cell is not also included. I gather from Ehrlich's papers, that both his cells with α-granulation (true oxyphil) and his cells with β-granulation must really be included in Wharton Jones's " coarsely granular leucocytes," and therefore I have included both of them together under that head in my countings.

It is a little difficult to assign to this cell a normal percentage in the blood, because it appears especially subject to numerical variation. In cat's blood I have found the cell usually rather more numerous than in dog's blood. Considering the two kinds of blood together, I

---

* ' Virchow's Archiv,' vol. 96, p. 61.

† ' Leçons sur l'Inflammation,' Paris, 1892.

‡ "Zur Frage der Blutbildung," 'Sitzungsb. d. Kais. Akad. Wien,' Abth. III, vol. 98, 1889.

should estimate the ordinary frequence as between 10 per cent. and 1·2 per cent. of all hæmic leucocytes.

C. The Hyaline Leucocytes.

This class is probably a less homogeneous collection than either of the other two. Two subdivisions of it are important. I. Small cells, lymphocytes. II. Larger cells, myelocytes. One however often meets with individuals in whose case one feels hesitation before deciding as to which of the two subdivisions they shall be assigned.

I. *Small Cells.*—These are, for the most part, M. Schultze's "smallest" cells; the nucleus is spherical, and stains deeply; the cell body is small, sometimes a mere film coating the nucleus. The cell body is apt to stain deeply with methyl blue and other basic dyes. I agree with Schultze that this cell is not amœboid in the blood. It also seems less sticky than the other leucocytes. In the counting solution the nucleus of this cell is the first living structure to become tinged with colour. When platelets (precipitate) are present these tinge even earlier, but of a violet colour, whereas the nucleus of the small hyaline cell takes at first a pure light blue; and there is no evidence that the platelets are living structures.

II. *Larger Cells.*—Some are among the largest of hæmic leucocytes. The cell body encloses a spheroid, ovoid, or reniform nucleus, the chromatin of which is patchily distributed, and not so condensed as in the partinucleate leucocytes. The cell body tinges in many individuals deeply and evenly with basic dyes, but in other individuals, as Everard, Demoor, and Massart[*] have especially pointed out, hardly at all. This cell is, in my experience, sluggishly amœboid. It is, however, phagocytic.

I have very frequently noted that in specimens in which the large hyaline leucocyte is numerous the small hyaline is also more numerous than in specimens in which the large hyaline cell is scanty. The two varieties seem to vary in the same direction. The number of hyaline leucocytes varies greatly in normal blood; I estimate it to average (in dog and cat) at between 5, 7, and 20 per cent. of the total leucocytes. When their number is large the blood is usually of low specific gravity, of low hæmoglobin value, and contains a relatively poor number of chromocytes, *i.e.*, the blood is polyplasmic.

The hyaline leucocytes probably correspond pretty closely with Löwit's[†] "mononuclear" class.

All hæmic leucocytes appear to me to be to a large extent anaërobic organisms. The amœboid varieties, for instance, continue amœboid

[*] "Sur les Modifications des Leucocytes dans l'Infection et dans l'Immunisation," 'Annales de l'Institut Pasteur,' p. 165, February, 1893.

[†] *Op. cit.*

for hours in sealed cells in which the hæmoglobin of the chromocytes exists in a reduced condition.

Having thus attempted to state definitely some characters on which I have depended for distinguishing one variety of hæmic leucocyte from another, I will proceed to a more detailed summary of the alteration in the numerical relations of the varieties, resulting from various forms of acute local inflammation.

As already pointed out, there occurs a diminution of the total number of hæmic leucocytes (a leucocytopenic phase), followed by an increase of the total number of hæmic leucocytes (a leucocytotic phase); finally, in some experiments there is again a leucocytopenic phase.

First.—*The Leucocytopenic Phase.*

This phase has in my experiments always been observable when the blood analysed was taken within a short time, e.g., less than an hour, after the establishment of the lesion.

The decrease in leucocytes affects the finely granular more than the hyaline, indeed, my countings do not show any absolutely indubitable decrease of the hyaline leucocytes. Remembering, however, that the apoplasmia of the blood is being established at this time, and that were the hyaline leucocytes to remain undiminished their number per unit volume of blood would be thereby increased, the actually slight fall of their number in my countings looks as if they did actually diminish in number, although to a less extent than do the granular varieties. The fall in their proportion to the chromocytes supports this belief, and seems larger than attributable to the errors inherent in estimations by sample.

Interpretations of the significance of the leucocytopenia seem to be still but doubtful inferences. The term leucocytopenia has been introduced by Löwit,[*] and expresses conveniently any relative scantiness of leucocytes such as that observed. Whether this inflammatory form of leucocytopenia is really the same in nature as the form consequent on binding down the animal, prolonged exposure, cooling, &c., described by Löwit, is not clear. Under those circumstances Löwit discovered the decrease of leucocytes to be especially due to decrease of the mononuclear variety (= broadly, the hyaline, in my countings). Whether, further, the inflammatory leucocytopenia is related to the other form of leucocytopenia (called, on theoretical grounds, leucolysis), admirably studied by Löwit, demands more attention here.

It has long been known that intravenous injection of a number of

---

[*] *Op. cit.*

substances, *e.g.*, fibrin ferment,[*] hæmoglobin,[†] septic fluids,[‡] pus, lymph cells,[§] hemialbumose,[||] peptones,[¶] pepsin,[¶] nucleic acid, nuclein,[**] leech extract,[††] tuberculin,[‡‡] pyocyanin,[¶¶] curare,[§§] uric acid,[§§] urates,[§§] dead bacterial cultures,[||||] bacterial extracts,[||||] bacterial proteins (Buchner),[¶¶] filtered yeast cultures,[§§] carmine in suspension,[***] produce more or less pronounced and rapid—often immediate—diminution of the number of leucocytes in the blood of the general circulation. This diminution has been shown by Löwit[†††] to be preliminary to a subsequent increase, and the phase of leuco-cytopenia, on account of its short duration, seems to have escaped the attention of many observers who have well recognised the much longer lasting subsequent leucocytosis. The diminution is sometimes enormous in degree. In some of Löwit's experiments the number of leucocytes fell in five seconds from the time of injection to less than one-twentieth the number circulating immediately previous to the injection. Löwit has discovered that the diminution, whether great or small, is at expense of the polynuclear leucocytes (the granular leucocytes of my countings). He opines that the diminution is due to destruction (he says the dissolving up) of these leucocytes. His conclusion harmonises with the view of the Dorpat school, according to which hæmic leucocytes are easily destroyed by a number of experimental procedures, some not obviously severe. As to curare, Drosdoff[‡‡‡] asserted, many years ago, that frog's leucocytes rapidly break down in blood serum (mammalian!) containing curare.

[*] Birk, 'Das Fibrin-Ferment im lebenden Organismus,' Dorpat, 1880.

[†] Bojanus, 'Exp. Beiträge z. Physiol. u. Pathol. d. Blutes,' Dorpat, 1881.

[‡] Hoffman, 'Ein Beitrag z. Physiol. u. Pathol. d. farblosen Blutkörperchen,' Dorpat, 1881.

[§] Samson-Himmelstjerna, 'Exp. Stud. ü. d. Blut in physiol. u. pathol. Beziehung.,' Dorpat, 1882.

[||] Löwit, *op. cit.*

[¶] Groth, 'Ueber die Schicksale d. farblosen Elemente im kreisenden Blute,' Dorpat, 1884; Löwit, *op. cit.*; Wright, 'Roy. Soc. Proc.,' February 9, 1893.

[**] Horbacewski, 'M. f. Chemie,' &c., Vienna, 1891, vol. 12, p. 221. Löwit, *op. cit.*

[††] Löwit, *op. cit.* (But Wright (*loc. cit.*) finds that intravenous injection of leech extract does not reduce the number of leucocytes.)

[‡‡] Tchistowitsch, 'Berlin Klin. Woch.,' p. 838, 1891; Botkin, 'Deutsch. Med. Woch.,' 1892, No. 15; Rieder, *op. cit.*

[§§] Löwit, *op. cit.*

[||||] Hankin and Kanthack, 'Proc. Cambridge Philosoph. Soc.,' January, 1892; Kanthack, 'Brit. Med. Journal,' 1892.

[¶¶] Werigo states that the injection of the filtered cultures does not give the reaction. Rieder, *op. cit.*

[***] Werigo, "Les Globules Blancs comme Protecteurs du Sang," 'Annal. Instit. Pasteur,' 1892.

[†††] *Op. cit.*

[‡‡‡] Hofmann und Schwalbe, 'Jahrsb.,' 1878, p. 67.

Rieder* has, however, urged that the leucocytes are not destroyed, but are merely collected or collect in some region of the circulation. This region they leave after a time, and then become again distributed generally through the circulation, when, according to Rieder, substances inducing positive chemotaxis reappear in the blood. Löwit points out that the *locus* of collection of the leucocytes is not made out by Rieder. Werigo,† on the other hand, has suggested that the leucocytes, after the intravenous injection of particulate material, crowd into and remain for a time in the liver, spleen, and lungs; for the lungs this has been proved by the recent work of Goldscheider and Jacob (*Verhandl. der Physiol. Gesellsch. zu Berlin*, xix, 1893). Everard, Demoor, and Massart‡ point out that the medulla of bone must be included in the loci of collection, and that the view can be extended to the results of injection of substances dissolved, as well as particulate. The recent experiments of Verhoogen§ are particularly interesting in this connection. Moreover, Wright‖ has lately shown that in the case of admixture of peptone with blood this diminution of leucocytes does not occur when the admixture is made, not in the circulation, but in blood withdrawn from the circulation. We cannot consider it as proven that the phenomenon of disappearance of leucocytes from the blood of the general circulation is really due to direct disintegration and dissolution of them, although the manner of their withdrawal from the general circulation has not yet been elucidated. Until the dissolution is proven, it is obvious that leucocytopenia is a better term for the observed phenomenon than is leucocytolysis.

A relation between the above " injection leucocytopenia " and the " inflammatory leucocytopenia " of my experiments seems indicated by the fact that in both the diminution is chiefly of the irregularly nucleate or granular cells. The connection is rendered still more probable from observations by Everard, Demoor, and Massart.¶ These investigators find a leucocytopenia (their hypoleucocytosis) usually precede the leucocytosis induced by subcutaneous and intraperitoneal injections, in considerable quantity, of bacterial cultures and culture fluids. This they attribute not to destruction of leucocytes, but to the leucocytes crowding into the blood vessels of the liver, spleen, and marrow, in virtue of chemotactic reaction. They conclude, further, that in their experiments, the leucocytopenia was chiefly due to diminution of the irregularly nucleate leucocyte, another point of resemblance between the leucocytopenia of the two procedures.

* *Op. cit.*

† *Op. cit.*

‡ *Op. cit.*

§ ' Travaux faits à l'Institut Solvay, Université de Bruxelles,' 1893.

‖ *Loc. cit.*

¶ *Op. cit.*

It is important in interpreting the significance of the inflammatory leucocytopenia to remember that the granular (= irregularly nucleate) hæmic leucocytes appear more adhesive than the hyaline (mononuclear, regularly nucleate). In the "balling" of leucocytes which so readily occurs in peptone blood, I have often noticed that the clumps of leucocytes may be formed almost exclusively of granular leucocytes, while many hyaline leucocytes are free in the plasma. In oxalated blood the granular leucocytes adhere to the masses of platelets disproportionately in comparison with the lymphocytes; they are not merely adherent to the surface of the masses but many are entangled and often remain for a time hidden *in* the masses. It is interesting to watch how those temporarily buried work their way to the surface. At first they appear like fusiform fibroblasts directed so as to radiate from the centre of the ball-shaped mass as it lies flattened between object-slide and cover-slip. The elongated nucleus is the chief sign of the cell, and this can be noted slowly slipping toward the periphery of the ball. As it approaches the free surface of the mass the cell glides more quickly, and finally it emerges with an almost sudden plunge and ranges itself beside the other similar leucocytes already sticking to the surface of the clump. Had one not seen the steps of the process one might have imagined that the cells covering the mass of precipitate had wandered to it on account of its nutritive nature (proteid) and in obedience to positive chemotaxis. As a fact however most at least of the cells have been merely mechanically entangled in the mass and gradually get out of it and then stick for a while to its free surface.

It must be remembered also that the hyaline leucocytes are not so amoeboid as the granular; the small variety of them not at all. Emigration will remove from the circulation more individuals of the granular than of the hyaline types. The granular leucocytes tend disproportionately numerously to adhere and escape in the vascular region of the local inflammation. This would increase the relative number of hyaline cells to granular in the general circulation.

Other possible factors may be briefly alluded to. Many of the substances that when injected into the circulation cause leucocytopenia are the *lymphagogues* of Heidenhain.* They belong to that class of lymphagogues which increase the flow of lymph from the thoracic duct by hastening the transfer of fluid from the blood into the lymph spaces. Heidenhain showed that in the dog these lymphagogues, although increasing the volume and organic richness of the output of lymph, *viâ* thoracic duct, reduce the volume and organic richness of the serum of the blood itself. Löwit† has shown that in the rabbit, as result of intravenous injection of albumose, &c., the

---

* *Op. cit.*
† *Op. cit.*

leucocytopenia and the lymphorrhœa occur together; but he does not find the apoplasmia of the blood noted by Heidenhain. In my experiments throughout the leucocytopenic phase of the blood the apoplasmia of it was obvious and steadily progressive. I have not yet systematically examined the flow of lymph from the duct in my form of experiment, but I have noted that the flow is sometimes increased, and that the lymph may contain hæmoglobin in solution. The absence of obvious increase, indeed the estimated decrease, of the ratio of hyaline leucocytes to chromocytes, as well as of hyaline leucocytes to granular leucocytes, indicates that any increased addition of hyaline hæmic leucocytes that may occur, *viâ* the thoracic duct, is out-balanced during the leucocytopenic phase by increased conversion of hyaline leucocytes into granular. There is, I take it, little doubt that many of the granular leucocytes are developed from the hyaline form (Kölliker, Virchow, &c.); and an increased rate of development si probable at the beginning of many forms of leucocytosis (Römer's[*] "*formativer Reiz.*")

In my experiments I have not found the leucocytopenia bear any very constant relation to the fever as judged by body temperature and respiratory rate. It may bear a closer relation to the process of apoplasmia; it seems to be slight when the apoplasmia is only slight.

Second.—*The Leucocytotic Phase.*

The time of onset of leucocytosis varied. It became obvious in something later than three-quarters of an hour after the establishment of the local lesion. In the ligation experiments it was particularly late. I did not detect any very constant relation between it and body-temperature or respiratory rate.

Its duration varied. It may be prolonged for several days and without much abatement.

The anatomical details of inflammatory leucocytosis have been recently reviewed and studied by Rieder.[†] I will merely point out that in my observations as in his the increase in the total hæmic leucocytes has been accompanied by upset of the normal numerical ratio of granular to hyaline (in his observations polynuclear to mononuclear) in favour of the granular leucocytes. Rieder saw the proportion rise sometimes to 20 : 1. I have seen it rise from 6·2 : 1 to 19·4 : 1.

In this feature again there is a resemblance between this form of leucocytosis and that ensuing upon injection of albumoses, bacterial cultures, &c., into the circulation. Hankin and Kanthack[‡] have

---

[*] ' Virchow's Archiv,' 1892.

[†] *Op. cit.*

[‡] *Op. cit.*

pointed out that the leucocytosis after bacterial injections is chiefly due to increase of the granular leucocytes; Löwit[*] has since shown the same thing for the leucocytosis following injections of albumose, nuclein, &c. In one of his experiments the polynuclear were to mononuclear leucocytes as 87 to 13. V. Limbeck,[†] and Everard, Demoor, and Massart[‡] note the same feature in the leucocytosis resulting from subcutaneous injections of bacterial cultures.

As to interpreting the meaning of the leucocytosis, Römer[§] has asserted that the increase of leucocytes is due to rapid multiplication of the leucocytes in the blood, especially in the blood of the veins. Kanthack[||] was, however, unable to confirm Römer's statement that the venous blood showed greater leucocytosis than the arterial; and Löwit[¶] has recently pointed out well-founded objections to Römer's observations. Löwit considers the leucocytosis due to increased supply of young leucocytes to the blood, these developing into the polynuclear form. Löwit supposes that the excessive production of leucocytes following their diminution (in his view their dissolution) is due to chemical stimulation of leucocyte-forming organs (lymph-glands, &c.) by substances shed into the blood plasma at the time of disintegration of the hæmic leucocytes. He considers this explanation applicable to all forms of leucocytosis, and from it argues the probability that "inflammatory leucocytosis" will be found to be preceded by a diminution of hæmic leucocytes. My experiments bear him out in that point; but, as to basing inflammatory leucocytosis on a previous dissolution of hæmic leucocytes my observations lend no help, and are capable of interpretation in other ways.

I think in my experiments the degree of leucocytopenia has not always been similarly proportioned to the succeeding leucocytosis. Since reproductive division of leucocytes, inclusive of the granular, polynuclear, or adult form, has now been shown to occur in the blood, the finely granular leucocytes may, therefore, increase in number by reproduction within the circulation.

Third.—*Behaviour of the coarsely-granular Leucocyte.*

A striking and I believe hitherto unrecorded feature of the change in the leucocytic elements of the blood relates to Wharton Jones's "coarsely-granular cell."

This leucocyte, like the other granular leucocytes, suffers numerical

[*] *Op. cit.*

[†] *Op. cit.*

[‡] *Op. cit.*

[§] *Op. cit.*

[||] "Acute leucocytosis produced by bacterial products," 'Brit. Med. Journ.,' June 18, 1892, p. 1301.

[¶] *Op. cit.*

reduction in the leucocytopenic phase, indeed it would appear to undergo even greater numerical decrease than the ordinary granular leucocyte with fine granules. But when the leucocytopenic phase passes off and the total number of granular leucocytes in the blood becomes greatly increased, their increase is due entirely to the "finely granular" cell, and there is no accompanying increase of the "coarsely granular" cell. On the contrary the number of the latter becomes still fewer, not merely in comparison with the rest of the polymorphic, but also in proportion to the number of chromocytes and, more striking still, absolutely as measured per unit volume of the steadily concentrating blood.

The diminution proceeds to such a degree that usually after the seventh hour from the time of establishment of the local lesion this species of leucocyte has been in my experiments only with some difficulty demonstrable in the blood. It disappears from the small samples used in the Thoma-Zeiss counters, and often from the larger samples employed in fresh and dried films spread on $\frac{5}{8}$ in. circular cover-slips. If the blood be examined by drawing 3 c.c. into a test-tube, oxalating, centrifuging, and making films from the separated layer of leucocytes, examples can usually be then found without very prolonged search, but at the ninth hour and later I have several times failed to find any, even by prolonged search, after separation by the centrifuge.

It seems, therefore, that in consequence of severe local inflammation the "coarsely-granular" hæmic leucocyte of Wharton Jones may practically disappear from the general circulation, although at the same time his "finely granular" hæmic leucocyte may be enormously increased in number.

As to the significance of this disappearance, two possibilities arise at once for consideration.

1. The cell may have become caught and so to say hidden in some part or parts of the vascular system, or have wandered out of the , blood circulation altogether.

2. The cell may have become so altered in appearance that it is not recognisable by the criteria I adopt for distinguishing it. Or its resistance to the procedures employed in looking for it may have become so lowered that it is destroyed in the process of search.

To take the last hypothesis first. I consider the coarsely granular hæmic leucocyte of the mammalian blood I have examined, to be normally one of the most resistant and easily preserved cells in the body. It can be frozen and thawed again, irrigated with 33 per cent. alcohol, with saturated ammonium molybdate solution, with strong aqueous solution of pyrogallic acid, with ammonium sulphide solution, with 0·3 per cent. acetic acid; it can be heated after partial drying to 120° C., and higher, and yet its granulation not be lost or *characters* distinctive of them destroyed, or the cell itself altered

beyond recognition. Now when the cell is discoverable only in scanty number in the blood, those individuals still present offer the same strikingly resistant quality as do the similar cells obtainable from normal blood. Yet in order on the above view to explain its disappearance from the blood, we have to suppose that in the simple process of the shedding of a drop of blood direct upon a clean coverglass, and the spreading of the drop into a film under the action of capillarity when the cover-glass is dropped upon the glass slide, the cell forthwith disappears to leave behind no recognised trace. This seems improbable, the more so as the search for the cell was in my case often commenced less than twenty seconds after it left the circulation.

The supposition that the appearance of the cell is altered, and that for that reason the cell, although still circulating, escapes recognition, merits more consideration.

Ehrlich was, I believe, the first to suggest that the coarsely granular leucocyte is a unicellular gland. From this suggestion one passes by a step, which is easy in the light of Heidenhain's and Langley's discoveries of phases of granularity in secreting cells, to the supposition that the granules of the coarsely granular leucocyte may disappear from it at certain periods of its activity. Recently Kanthack and Hardy[*] have most importantly extended some suggestive work by Hankin, and have proved that under bacterial irritation the coarsely granular leucocyte of the frog does actually change its appearance, and that the granules disappear from it more or less completely, while the surrounding microbes suffer damage.

Although bacteria were certainly never in the blood in my experiments it is impossible to suppose that this coarsely granular leucocyte discharges itself of granules under irritation of a bacterial kind only. The local inflammation in my experiments it is conceivable adds substances to the blood which may irritate these cells in the same way. If so it might be expected that in the frequent and prolonged examinations of these cells in living films, in hanging drops, &c , some good and indubitable evidence of the phenomenon should have met me. In the blood, say at the fifth hour, when the numerical disappearance of the cell is already advanced, there might have been expected, unless the disappearance of the granules is almost momentary, a certain number of cells in which the removal of the granules is incomplete. I have never observed any such appearance. In this connection I have especially borne in mind the occurrence of the subvarieties of the cell already mentioned. It is obvious that these subvarieties may be merely phases of development or degradation of charging or discharging of the cell; one of them certainly seems an

* 'Roy. Soc. Proc.,' December, 1892.

early phase of development. But I have never satisfied myself that the individuals of a subvariety became more numerous or less numerous in proportion to the typical cell. All of these forms appeared to be removed together.

Nor do I believe that the cell without its granules would have in most cases escaped recognition and passed muster with the other leucocytes. As stated above, the granules are far from being the only distinctive feature of the cell.

It is quite certain that, when the cells are being or have been reduced to a minimum in the blood, the remaining individuals are usually of perfectly normal granular appearance, active and unimpaired in their amœboid action. I have, in the stage just previous to the disappearance of the cell from ordinary films, made a dozen such films and left them, at various temperatures, protected from evaporation, and then examined them at different intervals of time to see if they did lose their granulation.

Many hæmic leucocytes, under certain circumstances, live a long time after removal from the body (frog's leucocytes nine weeks *in vitro*,* dog's leucocytes three weeks, kept cool, *in vitro*†). It might therefore have been expected that, if blood containing leucocytes which had freed themselves of their secretion granules were removed and kept alive *in vitro* for a time, the granules might be reformed. I placed samples of blood in which I was unable to find any leucocytes containing coarse granules *in vitro* under appropriate conditions, and examined it at repeated intervals; but I did not succeed in obtaining any reappearance of the coarsely granular cell. A great number of the leucocytes do, and before very long, become granular with fine and medium sized granules, and these granules are highly refractive and not basophil (*i.e.*, not micrococci). I have not satisfied myself that they are fatty. The mode of their appearance seems to be as follows :—

A great number of the finely granular leucocytes gradually become, as above mentioned, vacuolated. The vacuoles contain fluid, and are for the most part small and spherical, but some are larger and oval in shape. In most of the small vacuoles a single, fine, highly refracting particle, the size of a small micrococcus, is to be found, dancing under Brownian movement. In many of the vacuoles no particle at all is discoverable. In the larger vacuoles are obvious ingesta, but the bright particles in the small vacuoles do not seem to be ingesta because the plasma in which the cells lie is generally quite free from particles. The cells seem to exhibit the same vacuolation whether they have remained spherical and inactive as regards amœboid move-

* 'Zahn; *cf.* V. Kahlden, 'Ber. u. d. Verhandlungen der Path. Anat.,' Sect. a. d 10 Intern. Medic. Congress, Berlin, 1890.

† *Sherrington*, 'Intern. Congress of Physiol.,' Liège, 1892.

ment or not. The evidence rather indicates that the particles in the fine vacuoles are produced within the cells and not ingested. But that the particles are related to the granules of the coarsely granular cell there is no evidence to show. In cat's blood, where the true a-granule is cylindroid, the small round particles appearing in the leucocytes *in vitro* are *not* cylindroid nor are they so highly refracting; besides, they are much smaller, and their fineness leaves me in doubt over the phosphorus and oxyphil reactions of them.

If substances produced at the seat of local injury and inflammation leak into the circulation and there irritate the coarsely granular cell and produce lysis of its granules, some imitation of the process might be expected from the following experiment. Blood from which, when it circulated, the coarsely granular leucocytes were disappearing at an estimated rate of more than half a million per minute, was drawn and centrifuged, and the plasma obtained from it was added to normal blood containing plenty of coarsely granular cells. The coarsely granular cells 6, 12 and 24 hours afterwards, did not seem appreciably altered in number. In one instance two particular individuals of the cell were observed at intervals for 32 hours, sketched, and their granules counted; no change in size or number of their granules occurred.

I feel justified in believing, therefore, that the disappearance of the coarsely granular cell in inflammatory blood does not go on in such blood when placed *in vitro.*

Some observers hold that the various forms of hæmic leucocytes are not distinct species or varieties, but that they merely present the various aspects of one pleomorphic organism. If all kinds of hæmic leucocyte are thus transitionally related, it is possible that the coarsely granular cell can become actually one of the other hæmic cells. Unless this transition is wont to be effected very suddenly, the arguments I have adduced against, in the present instance, the disappearance of the cell from the circulation being due to lysis of its granules, apply for the most part against explanation by the pleomorphism hypothesis also.

An explanation that may be suggested is that chemical substances generated at the *locus læsionis* act on the blood just as Löwit[*] believes albumoses, &c. act when injected *intra venam, i.e.,* altogether destroy and dissolve certain of the leucocytes. The substances produced in the particular inflammations studied might destroy especially the coarsely granular forms. Does the coarsely granular form of leucocyte suffer even more severely than the finely granular when albumoses are injected intravenously? To test this I observed the leucocytes in samples of carotid blood drawn 3—6 minutes after injection of 2 grammes of hemialbumose (Grübler) (5 per cent. in 0·7 per cent.

[*] *Op. cit.*

aqueous NaCl solution) into the jugular vein of a small dog weighing 6 kilos. The countings showed the diminution of leucocytes to fall, as Löwit describes, chiefly on the polynuclear (granular) leucocytes, but the ratio of coarsely granular to finely granular forms did not appear indubitably altered.

Ehrlich* suggested that the hæmic leucocytes which contain his α-granulation (the "coarsely granular" of this Note) are derived from the oxyphil cells of bone-marrow. In one form of leucocythæmia the blood seems certainly to be laden with the oxyphil marrow cells. But the coarsely granular cell of the blood is not *exactly* an oxyphil marrow cell, for the latter is, as Rieder† and Muir‡ have pointed out, not an amœboid cell. That the granulation is in both the cells oxyphil does not establish the identity of the cells, nor even of the granulation ; a variety of substances are of the eosinophilous class. Dékhuysen§ failed to find any connexion between the hæmic leucocytes with α-granulation and the oxyphil granular plasma cells and connective tissue corpuscles.

Yet Ehrlich's view is supported by several facts. Thus I find the oxyphil granules of the marrow yield the Lilienfeld-Monti reaction to the same extent as the coarse granules of the hæmic cell. There is, too, correspondence between the shape of the granules in the cells from both sources ; thus I find

In the dog and rabbit, *small spheroid* granules in the coarsely granular leucocyte *and* in the oxyphil marrow cells.

In the horse, *huge granules, spheroid, occasionally almost cuboid* in the coarsely granular leucocyte *and* in the oxyphil marrow cells.

In the cat, *cylindroid granules* in the coarsely granular leucocyte *and* in the oxyphil marrow cell.

. But I have not been able to satisfy myself in my experiments that the oxyphil cells of the marrow are affected even when Ehrlich's α-granulation practically disappears from the blood.

As the coarsely granular leucocyte is not destroyed, or altered so as to escape preparation or recognition, it must be withdrawn from the general circulation, either by becoming fixed in some particular vascular region or by passing out of the blood vessels altogether. I have not yet sufficiently examined the anatomical character of the exudations to criticise these possibilities. The cellular characters of the exudation have seemed to vary greatly ; sometimes many cells closely resembled the coarsely granular hæmic leucocyte, but sometimes only a few.

* *Op. cit.*
† *Op. cit.*
‡ 'Journ. Path. and Bact.,' vol. 1, p. 133, 1892.
§ 'Verhandl. der Anat. Gesellschaft,' 1892. 'Anat. Anzeiger.'

The duration of the period of extreme poverty of the blood in this cell has varied in my observations between 18 hours and 6 days. In prolonged inflammation they may probably be scanty for much longer periods.

The degree of numerical elimination of the cell is illustrated by the following reckoning. In one experiment the cells fell from 13 per cent. of all leucocytes to less than 1 per 100 in the course of 12 hours. The animal was a large cat. Steinberg estimates the blood in the cat at 9 per cent. of the body weight; the animal weighed a little over 4 kilo. This would give 360 c.c. blood. In each mm. of blood there were at beginning of experiment about 15,300 leucocytes or 1,200 of the coarsely granular kind, making a total of 432 millions of the coarsely granulate in the circulation. Nine hours later no coarsely granular were found in the specimens examined on either of the two Thoma-Zeiss counters, nor were any found in several cover-glass preparations, but in specimens of blood centrifuged two of the cells were found in films of leucocytes from the leucocytic layer. In counting at random through these films 10,000 leucocytes were met with without meeting one coarsely granular cell. Allowing, however, that one existed for every 12,000 of the leucocytes, and knowing that the number of leucocytes had then risen to 36,100 per mm. of blood, the number of coarsely granular leucocytes in the circulation may be estimated at 1,080,000. On this calculation more than 400 millions of them had been withdrawn from the circulating blood in the course of nine hours. In the above example no allowance is made for the diminution in volume of the total blood (the specific gravity had increased from 1·056 to 1·061) which must have occurred but cannot have amounted to many c.c. The example is an extreme one, because the original percentage of these cells in the blood was high. But it gives an idea of the degree of impoverishment of the blood in these cells, and of the rate of their withdrawal (average rate of more than half a million per minute) from the general circulation. I detect at present no clear relation between the diminution of the number of coarsely granular leucocytes and the apoplasmia of the blood. When the apoplasmia developed late (ligation experiments) the withdrawal of coarsely granular leucocytes seemed hardly deferred. In the three experiments on the lung and pleural cavity apoplasmia was not produced, but the numerical reduction of the coarsely granular cells, though not so marked as usual, was unmistakable.

Under certain conditions, other than the above experimental ones, I have found the blood to contain very few coarsely granular leucocytes. I have already noted that fasting does not appear to decrease the number of them, but appears rather to increase it. At the same time, if prolonged to starvation point, fasting certainly appears to

greatly reduce the number of these cells. I judge so from their practical absence from the blood of three animals admitted into the Brown Institute in a destitute and starving state. Two of these animals did not recover, and autopsy revealed nothing but evidence of starvation, and slighter cases of the kind are not infrequently admitted at the Institution. I have also found the cell abnormally scarce in the blood at a late stage after thyroidectomy. The cell was scarce in the blood of a bitch which had thrown puppies twenty-four hours previously, though her temperature was normal. In a dog with a large subcutaneous abscess and in a horse with submaxillary abscess, I had great difficulty in finding any coarsely granular leucocytes, but the last two examples come under the same category as my own experiments, except that the local inflammatory conditions were subacute.

Canon* has concluded that the number of eosinophilous cells in the blood is increased in all diseases of skin. In a dog admitted with a severe scald of the back I found the blood almost destitute of these cells (coarsely granular), and it remained so for the first four days after admission. In the experiments in which skin was involved in the lesion (Series I) the diminution of the cells was as marked as in experiments where skin was not involved. Felsen† noticed in three cases of croupous pneumonia that at the height of the "fever" eosinophilous cells seemed absent from the blood. Noorden,‡ on the other hand, has seen a great increase in the number of eosinophilous cells in bronchial asthma at the time of the attack.

Hankin§ has made an interesting observation that the blood clots rapidly when the coarsely granular cell is scanty in the blood. I have pointed out|| that the coarsely granular cell does not initiate clotting in dog's blood. In the present experiments the blood, at a time when almost (perhaps actually) free from coarsely granular leucocytes, clotted very speedily and firmly, as is well known for blood in inflammation.

DESCRIPTION OF PLATE 1.

I wish here to thank very heartily Mr. A. F. S. Kent, to whose skill is due the success of the photomicrograms appended in illustration of some points described in the text.

FIG. 1.—"Coarsely granular" hæmic leucocyte of cat. Photographed while living. × 1000. The usual horseshoe shaped nucleus and the cylindroid granules are obvious. Zeiss apochromatic 2 mm.

---

* 'Deutsche Medic. Wochen.,' p. 206, 1892.
† 'Archiv f. Kinderheilkunde,' vol. 15, p. 78, 1892.
‡ 'Zeits. f. klin. Med.,' vol. 20, Part II, 1892.
§ 'Centralblatt f. Bacteriol.,' vol. 12, p. 777, 1892.
|| *Loc. cit.*

FIGS. 2 and 3.—"Finely granular" hæmic leucocytes (cat), incubated for twenty-four hours at 30° C, and beginning to undergo "vacuolation." In most of the vacuoles no particles are visible. Photographed while living. × 1000.

FIG. 4.—Two incubated leucocytes. In each the outline of the cell body is just visible; the nucleus, darkly stained with methylene blue, has been made to smear; before incubation the nuclei of the leucocytes would not smear.

FIG. 5.—"Finely granular" hæmic leucocyte (dog), killed very slowly (5° C, ten days). The nucleus has become spheroidal and excentric in position. When fresh the granules of the cell-body were exhibiting Brownian movement. Osmic vapour, then Ehrlich's logwood. × 1000.

FIGS. 6 and 7.—"Finely granular" hæmic leucocytes (dog), showing "rosette" form of nucleus commonly assumed. Blood oxalated and incubated for forty-eight hours. Fixation by drying over osmic vapour. Hæmatoxylin and eosin. × 1000.

March 1, 1894.

Dr. PERKIN, Vice-President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

In pursuánce of the Statutes, the names of the Candidates for election into the Society were read, as follows :—

Bateman, Sir Frederic, M.D.
Bateson, William, M.A.
Beevor, Charles Edward, M.D.
Bell, Robert.
Boulenger, George Albert.
Borne, Professor Alfred Gibbs, D.Sc.
Bovey, Henry Taylor, M.A.
Bradford, John Rose, M.D.
Bryan, George Hartley, M.A.
Burdett, Henry Charles.
Buzzard, Thomas, M.D.
Callaway, Charles, D.Sc.
Callendar, Hugh Longbourne.
Cheyne, William Watson, F.R.C.S.
Clarke, Sir George Sydenham, Major R.E.
Clowes, Professor Frank, D.Sc.
Corfield, William Henry, M.D.
Darwin, Leonard, Major R.E.

Dibdin, William J., F.C.S.
Downing, Arthur Matthew Weld, M.A.
Edgeworth, Professor Francis Ysidro, M.A.
Etheridge, Robert, F.G.S.
Froude, Robert Edmund.
Gray, Andrew, M.A.
Griffiths, Ernest Howard, M.A.
Haddon, Professor Alfred Cort, M.A.
Heycock, Charles Thomas, M.A.
Hickson, Sydney John, M.A.
Hill, George Henry, M.Inst.C.E.
Hill, Professor M. J. M., M.A.
Hinde, George Jennings, Ph.D.
Howes, Professor George Bond, F.L.S.
Jones, Professor John Viriamu, M.A.

Lansdell, Rev. Henry, D.D.
Lockwood, Charles Barrett, F.R.C.S.
Love, Augustus Edward Hough, M.A.
Lydekker, Richard, B.A.
McConnell, James Frederick Parry, Surgeon-Major, F.R.C.P.
Macewen, Professor William, M.D.
Mansergh, James, M.Inst.C.E.
Martin, John Biddulph, M.A.
Martin, Sidney, M.D.
Matthey, Edward, F.C.S.
Minchin, Professor George M., M.A.
Mott, Frederick Walker, M.D.
Notter, James Lane, Surgeon-Lieut.-Col.
Ord, William Miller, M.D.
Penrose, Francis Cranmer, M.A.
Power, William Henry.
Purdie, Thomas, B.Sc.
Reade, Thomas Mellard, F.G.S.
Rutley, Frank, F.G.S.
Salomons, Sir David, M.A.
Scott, Alexander, M.A.
Scott, Dukinfield Henry, M.A.
Seebohm, Henry, F.L.S.

Smith, Rev. Frederick John, M.A.
Stebbing, Rev. Thomas Roscoe Rede, M.A.
Stewart, Professor Charles, M.R.C.S.
Stirling, William, M.D.
Stuart, Professor T. P. Anderson, M.D.
Sutton, J. Bland.
Swan, Joseph Wilson.
Thomson, Professor John Millar, F.C.S.
Truman, Edwin Thomas, M.R.C.S.
Tuke, Daniel Hack, M.D.
Ulrich, Professor George Henry Frederick, F.G.S.
Veley, Victor Hubert, M.A.
Waterhouse, James, Colonel.
Webb, Francis William, M.Inst. C.E.
Whymper, Edward, F.R.G.S.
Wimshurst, James.
Windle, Bertram Coghill Allen, M.D.
Woodward, Horace Bolingbroke, F.G.S.
Wynne, William Palmer, D.Sc.

The following Papers were read :—

I. "Preliminary Note on Bilateral Degeneration in the Spinal Cord of Monkeys (*Macacus sinicus*) following Unilateral Lesion of the Cortex Cerebri." By E. L. MELLUS, M.D. Communicated by Professor V. HORSLEY, F.R.S. Received December 22, 1893.

(From the Pathological Laboratory of University College, London.)

Having for some time been engaged in an investigation of the question as to how far the fibres of each pyramid descend both halves of the spinal cord, I am in a position to state that in the bonnet monkey (*Macacus sinicus*) the following arrangement prevails.

Method of Investigation.—The animal being etherised, and the left hemisphere of the brain exposed by a single trephine hole (sometimes *enlarged afterwards*), a small portion of the excitable area of the

motor cortex was selected as detailed below, the selection being confirmed in each case by electrical stimulation. A small piece of the cortex, about 0·4 cm. square, constituting the focus of the movement observed, was removed, care being taken to remove also a little of the underlying corona radiata to be sure that no cortex was left. The wounds healed, without exception, within 24 hours by first intention. Beyond slight paresis, which generally disappeared in 24 hours, no symptoms were observed to result from the excision. Professor Horsley kindly did the operations for me. After three weeks the animals were killed, the brain and cord hardened in Müller's solution, and stained in osmic acid after the method of Marchi.

Results of Investigations.

Three foci of representation were selected for excision, the left hemisphere being chosen in every case (*vide* Method of Investigation).

> I. Focus for the movements of the thumb.
> II. Focus for the movements of the hallux.

The course taken by the descending degenerated fibres was as follows :—

I. *Hallux Focus removed.*—In this case the lesion consisted of the removal of about 16 sq. mm. of cortex between the superior precentral sulcus and the fissure of Rolando, and bounded below by the level of the superior frontal sulcus.

Degenerated fibres were found in both lateral columns of the cord, the large majority being on the right side. The degenerated fibres were scattered throughout the entire area of the crossed or lateral pyramidal tract, not being restricted to any special part of it, though it might be said they were a little more dense posteriorly. Throughout the cervical, dorsal, and lumbar regions the total number of degenerated fibres was not diminished, though, of course, relatively increased in the lower cord. In the pons and medulla the degeneration was entirely confined to the left pyramidal tract (the side of the lesion). At the decussation in the upper cervical region the degenerated tract divided; about one-third going to the lateral column of the same side, the remaining two-thirds crossing to the lateral tract on the opposite side. In the upper cervical region there were a very few degenerated fibres remaining in the direct tract (anterior column), and below the middle of the cervical enlargement none could be seen.

II. *Thumb Focus removed.*—In this case the lesion consisted of a similar removal of cortex at a point just above the lower end of the intra-parietal sulcus, and between it and the fissure of Rolando, and, consequently, just behind the inferior genu of the fissure of Rolando

Q 2

(Beevor and Horsley). As in the case of the hallux focus, degeneration was also confined to the pyramidal tracts of the same side (left) as the lesion, throughout the pons and medulla. At the decussation of the pyramids there was also a slight division of the degenerated fibres, but in this case a few fibres only (less than one in ten) went to the lateral column of the same (left) side of the cord. There may have been two or three degenerated fibres left in the direct tract after the decussation, but this could not be positively stated. In the cervical and upper dorsal regions the degenerated fibres gradually decreased in number. At the level of the second dorsal there were a very few degenerated fibres still left in each lateral column. At the third dorsal they had entirely disappeared.

It seems probable, from these observations, that a second decussation lower down in the cord—recrossing—does not occur, and that the bi-lateral degeneration observed by Pitres, Sherrington, Langley, Muratoff, and others is a genuine bi-lateral descent of fibres from one hemisphere.

II. "On the Relations of the Secular Variation of the Magnetic Declination and Inclination at London, Cape of Good Hope, St. Helena and Ascension Island, as exhibited on the Magnetarium." By HENRY WILDE, F.R.S. Received February 19, 1894.

In a paper which was read before the Royal Society in June, 1890, I showed that the principal phenomena of terrestrial magnetism and the secular changes in its horizontal and vertical components could be explained on the assumption of an electro-dynamic substance (presumably liquid or gaseous) rotating within the crust of the earth in the plane of the ecliptic, and a little slower than the diurnal rotation. By means of some electro-mechanism, new to experimental science, which I termed a magnetarium, the period of backward rotation of the internal electro-dynamic sphere required for the secular variations of the magnetic elements on different parts of the earth's surface was found to be 960 years, or 22·5 minutes of a degree annually. It was also demonstrated that the inclination of the axes of the electro-dynamic and terrestrial globes to each other of 20° 30', was the cause of the inequality of the declination periods about the same meridian in the northern and southern hemispheres; as instanced in the short period of outward westerly declination at London, and the long period of outward westerly declination at the Cape of Good Hope and St. Helena.

The object of the present communication is, firstly, to make a more

direct comparison of the declination periods at London and at the Cape of Good Hope than was set forth in my former paper; and, secondly, to show a further agreement between the indications of the magnetarium and the results of recent observations of the dip and declination at the Island of Ascension.

The rate of backward rotation of the internal electro-dynamic sphere, as I have said, is 22·5 minutes $= 0·375°$ annually. Now, the period of the westerly march of the declination needle at London from zero in the year 1657 to its maximum of 24° 30′ in the year 1817 is 160 years; therefore, $0·375° \times 160 = 60°$ of differential rotation of the internal sphere. Again, the westerly march of the needle at the Cape of Good Hope from the year 1609 to its maximum of 30° in the year 1881 is 272 years. Therefore, $0·375° \times 272 = 102°$ of differential rotation of the internal sphere. Hence, 60° : 160 years : : 102° : 272 years; the outward westerly declination periods at London and the Cape of Good Hope respectively, as shown by observation and on the magnetarium. Subjoined are tables of the declination and inclination at London, the Cape of Good Hope, and on the magnetarium for the same epochs.

Table I.—Secular Changes of the Declination and Inclination at London.

Epoch.	Declination.	Epoch.	Inclination.
1657	0° 00′	1723	74° 42′ N.
1665	1° 22′ W.	1773	72° 19′

ERRATUM.

Page 210, line 7 from bottom.

For 20° 30′ read 23° 30′.

Table II.—Secular Changes of the Declination and Inclination at London on the Magnetarium.

Differential motion of globes.	Epoch.	Declination.		Differential motion of globes.	Epoch.	Inclination.	
° 0	1657	° 0	00	° 0	1723	° 74	30 N.
6	1673	6	00 W.	6	1736	74	00
12	1689	10	00	12	1752	73	30
18	1705	15	00	18	1768	73	00
24	1721	17	30	24	1784	72	30
30	1737	19	30	30	1800	71	30
36	1753	21	30	36	1816	70	30
42	1769	22	30	42	1832	69	30
48	1785	23	30	48	1848	68	30
54	1801	24	00	54	1864	67	30
60	1817	24	30	60	1880	66	30
66	1833	24	00	66	1896	65	30
72	1849	23	30	72	1912	64	00
78	1865	22	30	78	1928	62	30
84	1881	22	00	84	1944	61	00
90	1897	21	30	90	1960	59	30
96	1913	20	30	96	1976	58	30
108	1945	18	30	108	2008	56	00
120	1977	16	30	120	2040	54	00
132	2009	13	30	132	2072	52	00
144	2041	10	30	144	2104	50	30
156	2073	7	30	156	2136	50	00
168	2105	4	00 W.	168	2168	49	30
180	2137	0	00	180	2200	49	00 N.

Table III.—Secular Changes of the Declination and Inclination at the Cape of Good Hope.

Epoch.	Declination.		Epoch.	Inclination.	
1605	0	30 E.	1751	43	00 S.
1609	0	12 W.	1770	44	25
1614	1	30	1775	45	19
1622	2	00	1780	46	46
1675	8	00	1792	47	25
1691	11	00	1818	50	47
1721	16	25	1836	52	35
1751	19	15	1839	53	06
1768	19	30	1846	53	40
1774	21	36	1880	57	00 S.
1780	22	16			
1783	22	23			
1788	24	04			
1792	24	31			
1818	26	31			
1836	28	30			
1839	29	09			
1842	29	05			
1845	29	07			
1850	29	18			
1880	30	00 W.			

Table IV.—Secular Changes of the Declination and Inclination at the Cape of Good Hope on the Magnetarium.

Differential motion of globes.	Epoch.	Declination.		Inclination.		
0	1609	0	00	27	00 S.	
6	1625	3	30 W.	27	30	
12	1641	6	20	28	00	
18	1657	9	40	28	30	
24	1673	12	30	29	00	
30	1689	15	00	30	00	
36	1705	17	20	32	00	
42	1721	19	40	34	00	
48	1737	21	40	35	30	
54	1753	23	20	37	30	
60	1769	24	40	40	00	
66	1785	26	20	42	30	
72	1801	27	40	46	00	
78	1817	28	30	49	00	
84	1833	29	00	52	00	
90	1849	29	40	54	30	
96	1865	30	00	56	30	
102	1881	30	00	58	00	
108	1897	30	00	60	00	
114	1913	29	30	61	30	
120	1929	28	20	63	00	
132	1961	26	00	66	00	
144	1993	22	30	68	00	
156	2025	15	30	70	00	
168	2057	8	00 W.	71	30	
180	2089	0	00	72	00 S.	

The secular changes of the magnetic elements at St. Helena are interesting from the fact that the declination period agrees well with the geographical position of this island, which is west of the meridians of London and the Cape of Good Hope.

The epochs of the zeros of the declination at these places are in the order of their longitudes respectively,

Cape of Good Hope ..... long. 18° 28' E. 1609.
London................ „ 0 0 1657.
St. Helena .... „ 5° 43' W. 1683.

As St. Helena is south of the equator, the outward westerly march of the declination needle has a long period which is not yet completed (prop. V). The length of this period, as shown on the magnetarium, is 256 years, and will arrive at its maximum in the year 1939.

Further proofs of the truth of the theory that the secular changes in the magnetic elements are caused by the rotation of an electro-

Table V.—Secular Changes of the Declination and Inclination at St. Helena.

Epoch.	Declination.	Epoch.	Declination.
1677	0 40 E.	1825	14 56 S.
1691	1 00 W.	1835	18 00
1724	7 30	1839	17 55
1775	12 18	1840	18 16
1789	15 30	1847	19 23
1796	15 48	1880	29 00 S.
1806	17 18		
1839	22 17		
1840	22 53		
1846	23 11		
1880	26 00 W.		

Table VI.—Secular Changes of the Declination and Inclination at St. Helena on the Magnetarium.

Differential motion of globes.	Epoch.	Declination.	Inclination.
0	1683	0 00	4 30 N.
6	1699	2 30 W.	4 00
12	1715	5 00	3 30
18	1731	8 00	2 30
24	1747	11 00	0 00
30	1763	13 00	2 00 S.
36	1779	15 00	5 00
42	1795	17 00	8 00
48	1811	19 00	11 00
54	1827	20 40	15 00
60	1843	22 20	19 00
66	1859	24 00	23 00
72	1875	25 30	28 30
78	1891	26 30	34 00
84	1907	26 40	37 00
90	1923	27 00	41 00
96	1939	27 20	45 00
102	1955	27 00	49 00
108	1971	26 40	52 00
114	1987	26 20	54 00
120	2003	26. 00	56 00
132	2035	24 00	60 00
144	2067	21 00	63 00
156	2099	18 00	66 00
168	2131	11 00 W.	67 00
180	2163	0 00	68 00 S.

dynamic substance within the earth's crust are afforded (1) by the dipping needle making only one downward or upward motion (outside the space comprised within the north and south limits of the magnetic equator) for the outward and return march of the declination needle, as instanced in the continued diminution of the dip in the British Isles during the westerly outward and return march of the declination needle since the year 1723. (2) From the secular changes of the dip in opposite directions about the same meridian in the northern and southern hemispheres, as instanced in the dip diminishing in the British Isles and increasing at the Cape of Good Hope and St. Helena for the same epoch (prop. X). (3) The rapid increase of the dip about the nodes of the magnetic equator, as first indicated by Sabine in the Gulf of Guinea and St. Helena. Before the time of my experiments no attempt had been made to assign a cause for the large and rapid change in the dip (about 17 minutes annually) on this part of the terrestrial surface until I found that the results obtained on the magnetarium agreed very closely with the observations. Subjoined are tables of the declination and inclination at St. Helena and on the magnetarium.

On working the inclination backwards on the magnetarium chronologically, it will be seen from the Table VI that about the year 1747 the dip changed the sign from south to north. As no observations were made on the dip at St. Helena previous to the year 1825, there is no record of this interesting fact, nor has it hitherto been deduced from theory.

A further confirmation of the agreement of the results obtained on the magnetarium with actual observations has recently been brought under my notice in the bulletin issued by the United States Coast and Geodetic Survey, No. 23, March 16th, 1891. In this publication

Table VII.—Secular Changes of the Declination and Inclination at Ascension Island and on the Magnetarium.

Ascension Island.			Magnetarium.		
Epoch.	Declination.	Dip.	Dip.	Declination.	Epoch.*
1834		1 ·57 N.	2 ·0 N.		66 ·5
1842	19 ·27 W.	0 ·08 S.	0 ·0	20 ·0 W.	69 ·5
1863	21 ·63	4 ·47	5 ·0 S.	21 ·0	77 ·0
1876	22 ·75	7 ·56	8 ·0	22 ·5	82 ·0
1890	23 ·00	11 ·37 S.	12 ·0 S.	23 ·0	87 ·5

* Annual differential motion of internal sphere 22'·5 = 0·375° from zero at London in the year 1657.

a table is given of the declination and dip at Ascension Island for the epoch 1834—1890, in which the change of the dip from north to south occurs between the years 1842—1839. The same change is not only shown on the magnetarium but also the amount of the dip and declination for the epoch 1834—1890.

The correlation of the maximum rate of change of the inclination with the minimum rate of change of the declination about the nodes of the magnetic equator is well seen in the observations, and is also demonstrated in my paper (prop. XVIII) and on the magnetarium.

III. " Terrestrial Refraction in the Western Himalayan Mountains." By General J. T. WALKER, C.B., R.E., F.R.S. Received January 13, 1894.

In the operations of the Great Trigonometrical Survey of India it is customary to determine the coefficient of refraction by reciprocal vertical observations between contiguous stations on the sides of all the principal triangles, and also as many as possible of the secondary triangles.

[The sum of the reciprocal vertical angles, *plus* the angle at the earth's centre, would be exactly equal to 180° if there were no refraction; the excess gives the sum of the refractions in both the angles, and half of it is taken as the amount for each angle.—March 2.]

The values of the coefficient thus obtained for the operations in the Western Himalayas—between the meridians of 73° and 80° east of Greenwich—have been grouped together for comparison in successive ranges of 2000 ft. of altitude between the elevations of 5,000 and 21,000 ft. above the sea level. The operations happen naturally to have been divided into two sections; for the regions lying between the great snowy ranges on the southern face of the Himalayas and the plains of India were first completed, and some time subsequently the still higher regions to the north, extending up to the Karakoram and Kuenlun Ranges, which look down on the plains of Turkestan. The first portion appertains to what is called the N.W. Himalayan Series, the second to what is called the Kashmir Triangulation. Thus the values of the coefficients of refraction were obtained separately for each section, and the results are shown in the following table, where the heights have reference to the middle points of the sides of the triangles, of which the number is given for each group :—

Ranges of height in feet.	Northern or Kashmir Triangulation.			Southern or N.W. Himalayan Series.		
	Number of sides.	Coefficient of refraction.	Probable error.	Number of sides.	Coefficient of refraction.	Probable error.
5,000 to 7,000	38	0·062	±0·003	34	0·069	±0·002
7,000 „ 9,000	61	0·058	0·002	36	0·073	0·003
9,000 „ 11,000	53	0·060	0·001	45	0·078	0·003
11,000 „ 13,000	51	0·055	0·001	20	0·071	0·004
13,000 „ 15,000	78	0·059	0·002	20	0·069	0·005
15,000 „ 17,000	70	0·047	0·001	19	0·074	0·005
17,000 „ 19,000	137	0·043	0·001	27	0·086	0·004
19,000 „ 21,000	59	0·041	0·003			

These results show that at each range of altitude the coefficient of refraction was greater in the Southern than in the Northern Section; also that from the height of 13,000 ft. upwards the coefficient decreased in magnitude, as it theoretically should do, in the Northern Triangulation, but, on the other hand, in the Southern it increased until it became twice as great as in the Northern. These differences of behaviour in the two regions are very curious and difficult to account for. They point to some difference in the atmospheric conditions to the north and south of the outer Himalayan Range, and this may possibly arise from the circumstance that the atmosphere to the south is more heavily laden with moisture than the atmosphere to the north; for the great southern range is the first to receive the clouds which come up from the Indian Ocean, and which are the chief source of Himalayan moisture; these clouds are mostly condensed into rain on the southern face of the range, and thus only a comparatively small portion of their contents is carried on beyond into the more northerly regions.

[Whatever the cause, the fact is very remarkable that the coefficient of refraction has a minimum value at an altitude of 20,000 ft. on the north side of the Himalayan ranges, and a maximum value at the same altitude on the south side.—March 2.]

IV. "On a Spherical Vortex." By M. J. M. Hill, M.A., D.Sc., Professor of Mathematics at University College, London. Communicated by Professor Henrici. Received January 19, 1894.

(Abstract.)

1. In a paper published by the author in the 'Philosophical Transactions' for 1884, on the "Motion of Fluid," part of which is moving rotationally and part irrotationally, a certain case of motion symmetrical with regard to an axis was noticed (see pp. 403—405).

Taking the axis of symmetry as axis of z, and the distance of any point from it as r, and allowing for a difference of notation, it was shown that the surfaces

$$r^2\left(\frac{r^2}{a^2}+\frac{(z-Z)^2}{c^2}-1\right) = \text{constant},$$

where a, c are fixed constants and Z any arbitrary function of the time, always contain the same particles of fluid in a possible case of motion.

The surfaces are of invariable form. If the constant be negative, they are ring-shaped; if the constant be zero, the single surface represented breaks up into an evanescent cylinder and an ellipsoid of revolution; if the constant be positive, the surfaces have the axis of revolution for an asymptote.

The velocity perpendicular to the axis of symmetry is

$$2\frac{k}{c^2}r(z-Z);$$

the velocity parallel to the axis of symmetry is

$$\dot{Z}-\frac{2k}{a^2}(2r^2-a^2)-2\frac{k}{c^2}(z-Z)^2,$$

where k is a fixed constant and $\dot{Z} = dZ/dt$.

These expressions (which make the velocity infinitely great at infinity) cannot apply to a possible case of fluid motion extending to infinity. Hence the fluid moving in the above manner must be limited by a surface of finite dimensions. This limiting surface must always contain the same particles of fluid.

Where, as in the present case, the surfaces containing the same particles of fluid are of invariable form, it is possible to imagine the fluid limited by any of them, provided a rigid, frictionless boundary, having the shape of the limiting surface, be supplied and the boundary

be supposed to move parallel to the axis of z with velocity $\dot{Z}$. Then the above expressions give the velocity components of a possible rotational motion inside the boundary. So much was pointed out in the paper cited above.

2. But a case of much greater interest is obtained when it is possible to limit the fluid moving in the above manner by one of the surfaces containing always the same particles of fluid, and to discover either an irrotational or rotational motion filling all space external to the limiting surface which is continuous with the motion inside it as regards velocity normal to the limiting surface and pressure.

3. It is the object of this paper to discuss such a case, the motion found external to the limiting surface being an irrotational motion, and the tangential velocity at the limiting surface as well as the normal velocity and the pressure being continuous.

The particular surface containing the same particles which is selected is obtained by supposing that the constant vanishes and also that $c = a$. Then this surface breaks up into the evanescent cylinder

$$r^2 = 0,$$

and the sphere $$r^2 + (z - Z)^2 = a^2.$$

The molecular rotation is given by $\omega = 5kr/a^2$, so that the molecular rotation along the axis vanishes, and therefore the vortex sphere still possesses in a small degree the character of a vortex ring.

The irrotational motion outside a sphere moving in a straight line is known, and it is shown in this paper that it will be continuous with the rotational motion inside the sphere provided a certain relation be satisfied.

This relation may be expressed thus:—

The cyclic constant of the spherical vortex is five times the product of the radius of the sphere and the uniform velocity with which the vortex sphere moves along its axis.

The analytic expression of the same relation is

$$4k = 3\dot{Z}.$$

This makes $$\omega = 15\dot{Z}r/(4a^2).$$

All the particulars of the motion are placed together in the table on p. 221, in which the notation employed is as follows:—

If the velocity parallel to the axis of r be τ, and the velocity parallel to the axis of z be w, then the molecular rotation is given by

$$2\omega = \frac{d\tau}{dz} - \frac{dw}{dr}.$$

The Motion of the Spherical Vortex $r^2 + (z-Z)^2 = a^2$ in an infinite Mass of Fluid parallel to the axis of z with uniform velocity $\dot{Z}$.

	Rotational motion inside sphere.	At the surface of the sphere.	Irrotational motion outside sphere.
Velocity parallel to axis of r	$3\dot{Z}r(z-Z)/(2a^2)$	$\tfrac{3}{2}\dot{Z}\sin\theta\cos\theta$	$3a^2\dot{Z}r(z-Z)/(2R^5)$
Velocity parallel to axis of z	$\dot{Z}\{5a^2 - 3(z-Z)^2 - 6r^2\}/(2a^2)$	$\dot{Z}(1-\tfrac{3}{2}\sin^2\theta)$	$a^2\dot{Z}\{3(z-Z)^2 - R^2\}/(2R^5)$
$p/\rho + V - \Pi/\rho$	$9\dot{Z}^2[(r^2 - \tfrac{1}{2}a^2)^2 - \{(z-Z)^2 - a^2\}^2 + a^4]/(8a^4)$	$\tfrac{3}{4}\dot{Z}^2\cos^2\theta + \tfrac{9}{8}\dot{Z}^2$	$\tfrac{1}{2}\dot{Z}^2\left[\begin{array}{l}\{5-4(a/R)^3-(a/R)^6\}\\ +9\cos^2\theta\{4(a/R)^3-(a/R)^5-(a/R)^6\}+\tfrac{9}{4}\end{array}\right]$
Current function	$3\dot{Z}r^2\{R^2 - \tfrac{4}{5}a^2\}/(4a^2)$	...	$-a^2\dot{Z}r^2/(2R^3)$
Surfaces containing the same particles of fluid throughout the motion	$3\dot{Z}r^2\{R^2 - a^2\}/(4a^2) = $ constant	...	$\dot{Z}r^2(R^2-a^2)/(2R^3) = $ constant
Velocity potential	...	...	$-a^2\dot{Z}(z-Z)/(2R^3)$
Molecular rotation	$15\dot{Z}r/(4a^2)$	...	...
Cyclic constant of vortex	$5a\dot{Z}$	...	...
Kinetic energy	$23\pi\rho a^3\dot{Z}^2/21$	...	$\pi\rho a^3\dot{Z}^2/3$

Also p is the pressure, ρ the density, and V the potential of the impressed forces.   The minimum value of $p/\rho + V$ is Π/ρ, where Π/ρ must be determined from the initial conditions.

Further R, θ are such that

$$r = R \sin \theta,$$

$$z - Z = R \cos \theta.$$

The whole motion depends on the following constants :—
  (1) The radius of the sphere a.
  (2) The uniform velocity $\dot{Z}$
  (3) The minimum value of $p/\rho + V$, viz., Π/ρ.

4. If c be not equal to a, then the surface containing the same particles when the constant vanishes breaks up into an evanescent cylinder and an ellipsoid of revolution.

Now, the velocity potential of an ellipsoid moving parallel to an axis is known. This velocity potential with a suitable relation between k and $\dot{Z}$ will make the normal velocity at the surface of the ellipsoid continuous with the normal velocity of the rotational motion inside the ellipsoid, but it does not make the pressure continuous.   Hence, if a motion of fluid outside the ellipsoid exist continuous with the rotational motion inside, then the motion outside the ellipsoid must be a rotational motion.

5. It cannot be argued that the application of Helmholtz's method to determine the whole motion from the distribution of vortices inside the ellipsoid must determine an irrotational motion outside the ellipsoid continuous with the rotational motion inside, because Helmholtz's method determines the irrotational motion by means of the distribution of vortices only when that distribution is known throughout space.   This is not the case of the problem under discussion. For here the rotationally moving liquid has been arbitrarily limited by rejecting all the vortices outside the ellipsoid, and it is not known beforehand that the rejection of these vortices is possible.

6. Yet on account of the interest of the problem the paper contains a calculation of the velocity components in Helmholtz's manner, supposing ꞏthe only vortices to be those inside the ellipsoid; *i.e.*, starting from the values of the velocity components

$$u = \frac{2k}{c^2} x (z - Z),$$

$$v = \frac{2k}{c^2} y (z - Z),$$

$$w = \dot{Z} - \frac{2k}{a^2} (2x^2 + 2y^2 - a^2) - 2 \frac{k}{c^2} (z - Z)^2,$$

the components of the molecular rotation are first found, viz.,

$$\xi = -k\left(\frac{4}{a^2}+\frac{1}{c^2}\right)y,$$

$$\eta = \left(\frac{4}{a^2}+\frac{1}{c^2}\right)x,$$

$$\zeta = 0.$$

Then the potentials L, M, N of distributions of matter of densities $\xi/2\pi$, $\eta/2\pi$, $\zeta/2\pi$ respectively throughout the ellipsoid are determined.

These are, outside the ellipsoid,

$$L = -\tfrac{1}{2}ka^4c\left(\frac{4}{a^2}+\frac{1}{c^2}\right)y\int_\epsilon^\infty\left(1-\frac{r^2}{a^2+u}-\frac{(z-Z)^2}{c^2+u}\right)\frac{du}{(a^2+u)^2(c^2+u)^{\frac{1}{2}}},$$

$$M = \tfrac{1}{2}ka^4c\left(\frac{4}{a^2}+\frac{1}{c^2}\right)x\int_\epsilon^\infty\left(1-\frac{r^2}{a^2+u}-\frac{(z-Z)^2}{c^2+u}\right)\frac{du}{(a^2+u)^2(c^2+u)^{\frac{1}{2}}},$$

$$N = 0,$$

where ϵ is the parameter of the confocal ellipsoid through x, y, z. Then

$$\frac{\partial N}{\partial y}-\frac{\partial M}{\partial z} = ka^4c\left(\frac{4}{a^2}+\frac{1}{c^2}\right)x\,(z-Z)\int_\epsilon^\infty\frac{du}{(a^2+u)^2(c^2+u)^{\frac{3}{2}}},$$

$$\frac{\partial L}{\partial z}-\frac{\partial N}{\partial x} = ka^4c\left(\frac{4}{a^2}+\frac{1}{c^2}\right)y\,(z-Z)\int_\epsilon^\infty\frac{du}{(a^2+u)^2(c^2+u)^{\frac{3}{2}}},$$

$$\frac{\partial M}{\partial x}-\frac{\partial L}{\partial y} = ka^4c\left(\frac{4}{a^2}+\frac{1}{c^2}\right)\int_\epsilon^\infty\left(1-\frac{2r^2}{a^2+u}-\frac{(z-Z)^2}{c^2+u}\right)\frac{du}{(a^2+u)^2(c^2+u)^{\frac{1}{2}}}.$$

To obtain the corresponding expressions inside the ellipsoid it is necessary to replace ϵ by zero.

Outside the ellipsoid $\dfrac{\partial N}{\partial y}-\dfrac{\partial M}{\partial z}$, $\dfrac{\partial L}{\partial z}-\dfrac{\partial N}{\partial x}$, $\dfrac{\partial M}{\partial x}-\dfrac{\partial L}{\partial y}$ are the differential coefficients of the potential function

$$-\tfrac{1}{2}ka^4c\left(\frac{4}{a^2}+\frac{1}{c^2}\right)(z-Z)\int_\epsilon^\infty\left(1-\frac{r^2}{a^2+u}-\frac{(z-Z)^2}{c^2+u}\right)\frac{du}{(a^2+u)\,(c^2+u)^{\frac{3}{2}}},$$

which, with a suitable value of k, gives the potential of the irrotational motion outside the ellipsoid moving parallel to the axis of z with velocity $\dot{Z}$.

But inside the ellipsoid $\dfrac{\partial N}{\partial y}-\dfrac{\partial M}{\partial z}$, $\dfrac{\partial L}{\partial z}-\dfrac{\partial N}{\partial x}$, $\dfrac{\partial M}{\partial x}-\dfrac{\partial L}{\partial y}$ are not respectively equal to the values of u, v, w from which the investigation commenced.

In fact

$$u = \frac{\partial P}{\partial x} + \frac{\partial N}{\partial y} - \frac{\partial M}{\partial z}$$

$$v = \frac{\partial P}{\partial y} + \frac{\partial L}{\partial z} - \frac{\partial N}{\partial x},$$

$$w = \frac{\partial P}{\partial z} + \frac{\partial M}{\partial x} - \frac{\partial L}{\partial y},$$

where P is the potential function

$$\left[\frac{k}{c^2} - \tfrac{1}{2} ka^4 c \left(\frac{4}{a^2} + \frac{1}{c^2} \right) \int_0^\infty \frac{du}{(a^2+u)(c^2+u)^{\frac{1}{2}}} \right] \{ r^2 (z-Z) - \tfrac{2}{3} (z-Z)^3 \}$$

$$+ \left[\dot{Z} + 2k - ka^4 c \left(\frac{4}{a^2} + \frac{1}{c^2} \right) \int_0^\infty \frac{du}{(a^2+u)^2 (c^2+u)^{\frac{1}{2}}} \right] (z-Z).$$

7. The expressions $\dfrac{\partial N}{\partial y} - \dfrac{\partial M}{\partial z}$, $\dfrac{\partial L}{\partial z} - \dfrac{\partial N}{\partial x}$, $\dfrac{\partial M}{\partial x} - \dfrac{\partial L}{\partial y}$ cannot be taken by themselves to represent the velocities inside and outside the ellipsoid, for, though they would furnish continuous values of the velocities at the surface of the ellipsoid, they would not make the pressure continuous.

V. "Researches on the Structure, Organisation, and Classification of the Fossil Reptilia. Part IX. Section 1. On the Therosuchia." By H. G. SEELEY, F.R.S. Received January 8, 1894.

(Abstract.)

This paper discusses the classification of reputed Permian and Triassic Reptilia which have been referred to the Anomodontia as Theriodonts.

Lycosaurus, as the genus placed first on the Sir R. Owen's list, is accepted as the type of the Theriodontia. The species *Lycosaurus curvimola* is regarded as the type of the genus, being the only species in which its characters are fully shown. *Galesaurus planiceps*, which was the type of the Cynodontia, is probably distinct from *Nythosaurus larvatus*, and from Sir R. Owen's second type of *Galesaurus planiceps* of 1887, which is referred to as *Thrinaxodon liorhinus*. *Ælurosaurus felinus* agrees with *Galesaurus* in having a transverse development of bones of the palate, regarded as palatine and transverse, which abut toward the inner side of the lower jaw. The palate in this genus is found to be covered with groups of small teeth with conical crowns,

which are unknown in *Lycosaurus*. The palate of *Lycosaurus curvi-mola* is found and described in the type specimen. It shows a transverse development of the palatine arch abutting against the lower jaw, behind which is a long compressed sphenoidal keel flanked by narrow pterygoid bones. The occipital condyles do not appear to be prominently developed in *Lycosaurus*. The genus is regarded as the type of a division of the Theriodontia, defined by having the molar teeth pointed and without cusps. A snout from Tamboer, named *Pristerognathus polyodon*, is referred to this group. It is characterised by six incisor teeth in each premaxillary bone and three incisor teeth in each ramus of the mandible, followed by canine teeth and small molars of Lycosaurian type.

Professor Cope's definition of the Theriodontia as distinguished from the Anomodontia by characters of the post-orbital arch is regarded as unsupported by evidence. The author would limit the Theriodontia to animals which conform to Sir R. Owen's original definition based on the dentition (1876), and have temporal vacuities and a small quadrate bone. It would then include the Lycosauria, with type *Lycosaurus curvimola;* the Cynodontia, with *Cynognathus cratero-notus* (n.sp.) and *Thrinaxodon liorhinus* as types; and a group of South African Reptiles named Gomphodontia, based upon new genera *Gomphognathus* and *Trirachodon*, which have the molar teeth with flattened cuspidate crowns more or less worn with use. The palate is formed on the type of *Lycosaurus* in these Theriodontia.

Gorgonops is closely allied to Theriodonts in its dentition (though no molar teeth are known). The skull is closed behind as in *Kiste-cephalus*, and the temporal vacuities are roofed. It appears to show a palate formed on the same plan as in Theriodontia so far as its transverse development is concerned, but it has not any hard palate extending above the posterior nares as in Theriodontia. It is regarded as the type of a distinct group, named Gorgonopsia.

The Pareiasauria have the same transverse palatine arch, abutting against the lower jaw, but not developed downward to the same extent, as in Theriodontia. Its hard palate appears to be carried back behind the teeth, so that the posterior nares are further back than in the Theriodontia. It differs from the Theriodontia in the slight development of the coronoid process of the lower jaw, and in having the temporal vacuities roofed; and from the Gorgonopsia in having the skull open behind, and in having no canine teeth.

The Endothiodont type is believed to show the transverse descending palatal arch between the rami of the mandible. *Pristerodon* is regarded as possibly Endothiodont; and *Endothiodon uniseries* is made the type of a genus *Esoterodon*. A small skull from Molteno Pass, *Cryptocynodon simus* (n.sp.), is regarded as an Endothiodont with imperfectly-developed canine teeth. The Endothiodontia have

Q 2

no incisor teeth, have the hard palate imperfectly developed, and no coronoid process to the lower jaw.

Another South African group is regarded as indicated by *Delphino-gnathus, Tapinocephalus,* and a new genus named *Dinocephalus,* which has the largest tusks known in any South African genus, associated with small molars. In the typical genera the skull bones are very thick and the temporal vacuities small. *Ælurosaurus* is probably to be placed in this group. It is referred to as Dinocephalia.

Thus there is a series of groups of South African Reptilia which appear to agree in having a palate which has some resemblances to Mammals but approximates to *Sphenodon,* Lizards, and Crocodiles. All these sub-orders are combined as the Therosuchia. In this order or group may be included the Deuterosauria from the Permian rocks of Russia.

The Deuterosauria is distinguished from the Theriodontia by having palato-nares which open by oval vacuities on a concave surface instead of behind a hard palate. The transverse palatine arch is not developed downward. The sphenoidal region is at an angle with the palate, and in the same plane with the occiput.

Finally, the names given by Professor Cope to allied American types are examined. It appears that the Theromora as hitherto used is a synonym of the Anomodontia, though it might be conveniently limited to the American types, which appear to be distinct from those of Africa and Europe. But it is not possible to use either that name or the names Pelycosauria or Cotylosauria till the characters of the groups they indicate are adequately defined by good characters.

The relation of the Therosuchia to other Anomodontia is shown in the following grouping.

ANOMODONTIA.
    THEROSUCHIA.
        Pareiasauria.
            Procolophonia.
        Gorgonopsia.
        Dinocephalia.
        Deuterosauria.

        Theriodontia. { Lycosauria.
                      Cynodontia.
                      Gomphodontia.

        Endothiodontia.
        [Theromora.]
    THEROCHELONIA.
        Dicynodontia.
        Kistecephalia.
    MESOSAURIA.

VI. " Researches on the Structure, Organisation, and Classification of the Fossil Reptilia. Part IX. Section 2. On the Reputed Mammals from the Karroo Formation of Cape Colony." By H. G. SEELEY, F.R.S. Received January 4, 1894.

(Abstract.)

The author re-examines the remains of *Theriodesmus*, and contests the interpretation of the carpus given by Professor Bardeleben, producing specimens of South African Reptiles in which there is a single bone beneath the radius, as in *Theriodesmus*. This character is shown in a small skeleton, at present undescribed, which the author obtained from Klipfontein, Fraserberg, which he regards as referable to a new genus. Other evidence is produced supporting the interpretation of three bones in the proximal row in the carpus, in a specimen from Lady Frere. The author then compares the forelimb of *Theriodesmus* with that of *Pareiasaurus*, which was obtained subsequently, and arrives at the conclusion that the types of limb are too closely related to be referred to different orders of animals, and therefore that *Theriodesmus* must be transferred from the Mammalia to the Therosuchia.

The skull described as *Tritylodon longævus* is examined, and its close resemblance to the skulls of new Theriodonts is pointed out. The author believes that it shows evidence of possessing both prefrontal and post-frontal bones, which were situate as in Theriodonts, and circumscribed the orbits in the same way; so that, although the post-frontal bones appear to have met in the median line to form a crest, at the back of the frontal, there is no other character in the skull by which it can be distinguished from the skull of a Theriodont. It therefore appears to be reptilian, and thus would make known divided roots to the molar teeth in Reptilia, and a more complicated type of crown than in any Theriodont yet known.

VII. " Researches on the Structure, Organisation, and Classification of the Fossil Reptilia. Part IX. Section 3. On *Diademodon*." By H. G. SEELEY, F.R.S. Received January 12, 1894.

(Abstract.)

The author describes fragments of jaws and teeth from Upper Karroo strata at Wonderboom and Aliwal North, collected by R. D. Kannemeyer and Alfred Brown. They may possibly belong to more

than one genus ; but, in absence of sufficient knowledge of the skull
to establish differences, the four species are referred to a new genus,
Diademodon. Its, hinder molar teeth have undivided roots, and low
crowns, which are subquadrate or transversely ovate, surrounded by a
diadem of low cusps, which are chiefly developed on the external and
internal borders, with crenulations or minute cusps on the anterior
and posterior margins of these teeth.   There is a low central cusp
in the middle of the crown from which slight ridges extend, chiefly
in the transverse direction ; but in the type species these ridges
take the form of a cross.   The species are distinguished by the form
of the crown and the details of the cusps.   The upper and lower
teeth are opposed so as to be evenly worn, but the mandibular
teeth are narrower.

These teeth are highly specialised, but distinct in plan from
Tritylodon, and from all known Reptiles.   They closely approximate
to some of the higher Mammalia.   The author refers *Diademodon*
to a division of the Theriodontia in which the teeth become worn
with use, which is named Gomphodontia.

VIII. " On the Effect of Magnetisation upon the Dimensions
of Wires and Rings of Annealed Iron."   By SHELFORD
BIDWELL, M.A., LL.B., F.R.S.   Received February 14,
1894.

In the year 1885 I submitted to the Royal Society the first of a
series of papers* upon the changes produced by magnetisation in the
dimensions of rods, &c., of iron and other magnetic metals.   The
chief, and perhaps the most interesting, subject of the paper was the
observation that if the magnetising force were sufficiently increased,
the extension which a magnetised iron rod at first underwent (as
originally noticed by Joule†) was followed by contraction, the rod
ultimately becoming shorter than when it was unmagnetised.   The
elongation was generally found to attain a maximum with a magnet-
ising force of from 80 to 120 C.G.S. units, and to vanish with a force of
300 to 400, retraction occurring when still higher forces were applied.

From that date until quite recently no accounts of similar experi-
ments by other workers have, so far as I know, been published.
About the beginning of last year, however, it was stated in the
scientific journals that M. Alphonse Berget had investigated the
magnetic dilatation of iron in strong fields, and had found that the
length of his bar was still increasing when the magnetic field had

* ' Roy. Soc. Proc.,' vol. 40 (1886), pp. 109, 257 ; vol. 43 (1888), p. 407; vol. 47
(1890), p. 469 ; vol. 51 (1892), p. 495.   ' Phil. Trans.,' vol. 179, A (1888), p. 205.
† Joule's 'Scientific Papers,' pp. 46 and 235.

reached as high a value as 540 units, beyond which point the experiment was not carried.

On reference to the original paper in the 'Comptes Rendus,'[*] it appeared that the experiment was made with a cylindrical bar, measuring 5·2 cm. by 1·95 cm., its length being less than three times its diameter. The actual magnetising force must therefore have been enormously less than that due to the coil itself, and it is very improbable that it ever reached the value at which the iron (or the greater portion of it, for the magnetisation must have been far from uniform) would attain its maximum extension.

The 'Phil. Mag.' of December, 1893, contains an account of some experiments by Mr. Sidney Lochner, made, as he states, with the express object of determining whether M. Berget's results or my own were correct. Using a thin iron rod, he obtained a curve very closely resembling those published by myself; but, as might have been expected, he found that a short thick rod, like that of M. Berget, gave no decided indication of having passed a maximum extension within the limits of the magnetising force that he employed.

A paper of great interest, on "Hysteresis attending the Change of Length by Magnetisation in Nickel and Iron," by Mr. H. Nagaoka, published in the 'Phil. Mag.' for last January, also incidentally confirms my observations.

In subsequent papers I have shown how the elongations and retractions were modified by tension, and by the passage of electric currents through the specimens under examination; and in the present communication I propose to deal with the somewhat unexpected effects which were produced by carefully annealing the iron before using it.

Upon this point, Joule's observations are as follows:—" On inspecting the tables, it will be remarked that the elongation is, for the same magnetic intensity, greater in proportion to the softness of the metal. It is greatest of all in the well annealed iron bars, and least in the hardened."[†]

The current belief, in which till quite recently I myself shared, is in accord with this statement. It appears, however, as will be shown, that it represents the reverse of the truth. Joule's conclusion with regard to iron seems to have been based entirely upon the results of a single experiment with an unannealed bar, and he may possibly have been mistaken in supposing that it consisted of the same quality of iron as the annealed bars which he had used before.

My own experiments, the results of which are given in Table I and fig. 1, were made with a piece of iron wire, 10·6 cm. in effective length and 0·265 cm. in diameter. The curve marked (1) shows the behaviour of the iron in the condition in which it was bought. Its

---

[*] 'Comptes Rendus,' November 7, 1892, p. 722.

[†] Joule's 'Works,' p. 246.

length increased rapidly with the magnetising force, the maximum increment which was obtained in a field (due to the coil) of about 140 units being as much as 45 ten-millionths of the length of the wire. The same wire was then carefully annealed, and the experiment repeated, with the results indicated in curve (2). It will be seen that the maximum increment had fallen from 45 to about 8 ten-millionths—less than one-fifth of its former value—and was reached with a force of about 60 units. Finally, the wire was raised to a bright red heat in a blowpipe flame, and dropped into cold water, its subsequent performance being as indicated in curve (3). This last operation was found to have raised the maximum elongation from 8 to 25 ten-millionths, while the corresponding magnetising force had increased from 60 to about 110 units.
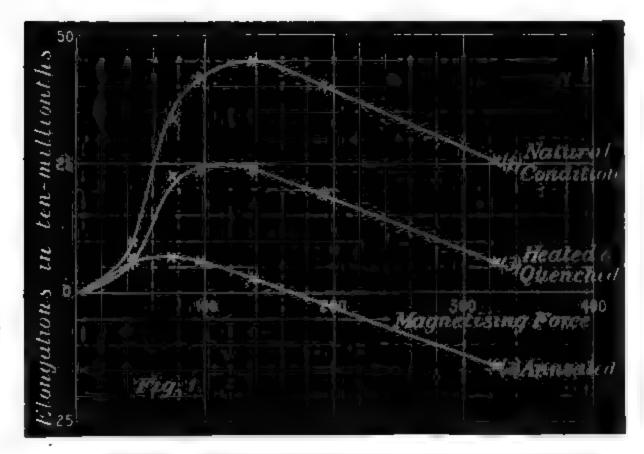

Fig. 1.

Table I.

Magnetising force C.G.S. units.	Elongations in ten-millionths of length.		
	Iron as bought (1).	Annealed (2).	Made red hot and quenched (3).
	10	7·0	6
74	34	7·0	23
96		6·0	24
138	45	3·5	24
	40	− 1·2	19
324	25	−17·0	6

Other experiments gave results of a similar character, and many attempts were made to obtain an annealed wire which would not be lengthened at all by magnetisation, but begin to contract from the first, like nickel and cobalt. But I never succeeded in bringing a wire into such a condition that its maximum elongation was less than 7 or 8 ten-millionths.

Though I failed with straight wires, however, I was perfectly successful with an iron ring.

I have in a former paper given an account of some experiments made with rings.* The changes in the diameter of a ring were found to be of just the same character as those observed in straight rods. With a continuously increasing magnetising force the diameter first increased in length, and, after passing a maximum, ultimately became shorter than at starting.

In those experiments three different rings were employed, not one of which had been annealed before being used; I therefore had a new ring made of good soft iron, and very thoroughly annealed. It was afterwards fitted with a boxwood jacket, around which 515 turns of insulated wire were wound in the usual way. With this ring it was found that the smallest currents which caused any effect at all produced contraction; there was no indication of the smallest preliminary extension.

The results of an experiment with the ring (which I shall call Ring I) are given in Table II and in the lower curve of fig. 2. The latter bears a close resemblance to the earlier portion of the curve given by a rod of cobalt. The greatest retraction reached was nearly 75 ten-millionths (exceeding any that has been ever before obtained with iron), and from the appearance of the curve there is reason to believe that this was still far from its limiting value, but the heating effect of the magnetising current made it impossible to carry the experiment further.

---

* 'Phil. Trans.,' 179, A, p. 205. A ring is prepared for the experiment in the following manner :—Short brass rods are attached to it at opposite ends of a diameter, forming prolongations, which serve to transmit the effect of changes in the length of the diameter to the measuring instrument. The ring is then covered with a loosely fitting boxwood jacket, also ring-shaped, and through holes in this the two brass rods protrude. The magnetising coil is wound directly upon the wooden ring, the object of the latter being to protect the iron from the heat generated when a current is passing through the coil.
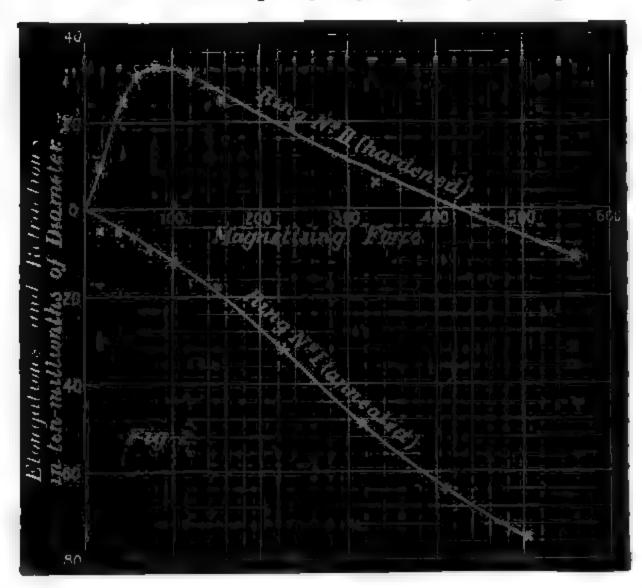
Elongations and Retractions in ten-millionths of Diameter.

40

Ring N° II (hardened).

30

0   100   200   300   400   500   600

Magnetising Force

20

Ring N° I (annealed).

40

Fig.

60

80

Table II.

Ring I (annealed).		Ring II (hardened).	
Magnetising force C.G.S. units.	Elongations in ten-millionths of length.	Magnetising force C.G.S. units.	Elongations in ten-millionths of length.
15	− 4·5	15	10
39	− 5·6	42	▓
56	− 6·2	61	21
73	− 9	81	33
101	−12	119	▓
152	−18	155	25
226	−32	239	▓
312	−49	328	6
410	−64	▓	▓
506	−75	560	−11

I at first contemplated unwinding the wire, hardening the iron, and repeating the experiment with the same ring; but felt unwilling to

run the risk of spoiling so remarkable a specimen which it might turn out to be difficult or impossible to replace. I therefore had another ring made of iron from the same parcel, and believed to have been cut from the same bar as the first. As, however, there was some doubt about this latter point, I thought it better in the first instance to anneal the new ring, and test it with a few turns of wire wound upon it. Its behaviour was found not to differ materially from that of Ring I. A very small elongation—too small to be measurable— was, however, observed with a magnetising force of only 3 C.G.S. units, contraction beginning when the force was increased beyond this value. The ring was then made red hot, and plunged into cold water, with the object of hardening it, after which operation it was replaced in its boxwood jacket and wound with 473 convolutions of wire.

This ring, called Ring II, was now found to give the same results as the old unannealed rings and straight wires. As appears in Table II and fig. 2, it attained its maximum elongation of about 33 ten-millionths in a field of 80, its original length was recovered in a field of about 440, and a retraction of 11 ten-millionths occurred in a field of 560.

It appears, therefore, that as regards magnetic changes of dimensions, an iron rod or ring is affected by annealing in very nearly the same manner as by tensile stress,* a result which would hardly have been anticipated.†

Notes regarding Details.

The apparatus and methods of experiment were the same as those fully described in 'Phil. Trans.,' vol. 179, A, pp. 218—224, the instrument being arranged so as to have a magnifying power of 43,745.

The height of each little square in fig. 2 corresponds to a length of about one-millionth of an inch (0·00000088 in. for Ring I and 0·00000103 in. for Ring II).

The wires and rings were demagnetised by reversals before every single observation. For a description and diagram of the demagnetising apparatus, see *loc. cit.*, p. 207.

---

* 'Roy. Soc. Proc.,' vol. 47 (1890), p. 469.

† The less so since the length of an iron rod seems to be diminished by annealing. A piece of iron wire 100 mm. long, cut from the same hank as that used in the experiments, was heated in a Bunsen flame, and slowly cooled. It was found to have contracted 0·07 mm., *i.e.*, 0·07 per cent. It was then heated in the blowpipe flame, and dropped into cold water. This produced an elongation of about 0·02 mm., leaving the wire 0·05 mm. shorter than it was originally. These measurements were made with a rough apparatus extemporised for the purpose, and I do not attach much importance to the quantitative results, though there can be little doubt that they are qualitatively correct.

The dimensions of the iron rings and their boxwood jackets were as follows :—

	Ring I.	Ring II.
Rings—		
External diameter......	6·9 cm.	6·1 cm.
Width.................	2·9 „	3·0 „
Thickness	0·4 „	0·35 „
Mean radius	3·25 „	2·82 „
Boxwood jackets—		
External diameter......	7·7 „	6·9 „
Width.................	3·7 „	3·8 „
Thickness.............	1·3 „	1·15 „
Convolutions	515	473
Gauge of wire	0·91 mm.	0·91 mm.

The rings were formed from rectangular bars with welded joints, and were turned in the lathe to the above dimensions.

The magnetic fields were calculated from the formula $H = 2ni/r$ where n is the number of convolutions, i the C.G.S. current, and r the mean radius.

The current was derived from a battery of twenty-seven storage cells used for lighting the house.

IX. "On Correlation of certain External Parts of *Palæmon serratus*." By H. THOMPSON. Communicated by Professor WELDON, F.R.S. Received January 25, 1894.

In 1890 Professor Weldon published ('Roy. Soc. Proc.,' vol. 47, p. 445) the results of measurements of certain organs of the common shrimp, with a view to establish by accurate data the degree of variation existing in those organs. In a later paper ('Roy. Soc. Proc.,' vol. 51, p. 2) he determined, by Mr. Galton's method there described, the degree of correlation existing between four organs of the same animal, and in a recent paper ('Roy. Soc. Proc.,' vol. 54, p. 318) similar determinations have been worked out by him for certain organs of *Carcinus mœnas*.

Some time ago it was suggested to me by Professor Weldon that I should determine the values of correlated variations in a number of parts of the hard exoskeleton of the common prawn (*Palæmon serratus*). Accordingly, 1000 adult female prawns, chosen at random, were procured from Plymouth and measured. Twenty-two measurements were made of each prawn, except in the case of two or three measurements which were made on part only of the sample.

The parts measured were the following :—

    I. Length of body from tip of rostrum to end of telson (excluding terminal spines).

    II. From hindermost point of orbit to hinder edge of carapace in a straight line.

    III. From tip of rostrum to median point of hinder edge of carapace.

    IV. From tip of rostrum to tip of first dorsal spine.

    V. From tip of rostrum to tip of last (hindermost) dorsal spine.

    VI. From tip of first to tip of last dorsal spine.

    VII. From tip of last dorsal spine to tip of the last but one.

    VIII. From tip of last dorsal spine to median point of' hinder edge of carapace (post-spinous portion of carapace).

    IX*a*. The right squame from tip of tooth to posterior edge of the external articular tubercle.

    IX*b*. The left squame measured in like manner.

    X. The anterior and posterior median points of the 1st abdominal tergum.

    XI. Posterior portion of the 1st abdominal tergum measured in like manner.

    XII. The 2nd abdominal tergum measured in like manner.

    XIII. The 3rd   ,,   ,,   ,,   ,,

    XIV. The 4th   ,,   ,,   ,,   ,,

    XV. The 5th   ,,   ,,   ,,   ,,

    XVI. The 6th   ,,   ,,   ,,   ,,

    XVII. The telson from the median point of the anterior edge to the tip of the median posterior projecting tooth (*i.e.*, excluding the terminal spines).

    XVIII*a*. Exopodite of the 6th abdominal right appendage from the tip of the dorsal or fixed tooth to the posterior edge of the dorsal articular tubercle.

    XVIII*b*. Exopodite of the 6th abdominal left appendage measured in like manner.

    XIX*a*. From base of lateral spine projecting from the posterior end of the telson to the base of the posterior spine on the dorsal surface of the telson on the right side.

    XIX*b*. Similar measurement for the left side.

Measurements I to III were made with compasses, and may be regarded as accurate to within about 0·5 mm., except No. I, the body length, which is somewhat less accurate. The remaining measurements were made under a microscope, and are accurate to within 0·05 mm.

For the purpose of comparison the measurements are all expressed in terms of the body length, which is taken as = 1000.
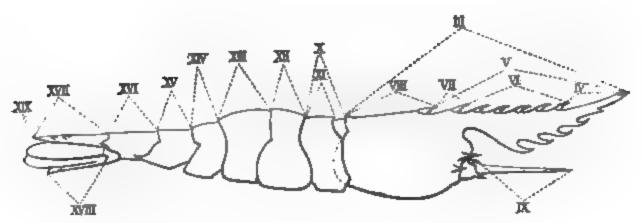
Diagram of exoskeleton of *Palæmon serratus* with appendages removed.   The
numerals refer to the numbers of the measurements.

Out of the 1000 prawns seven had a deformed rostrum, and six
had a deformed telson.   In several of the numerical results set out
below these thirteen animals have been excluded because their deform-
ities affected the body length to such an extent as to give a wholly
fictitious value to the reduced measurements of the other organs.

The existence of a long rostrum in the prawn has proved a serious
hindrance, since its length in proportion to that of the body is very
variable, and hence those parts in which the rostrum is an element
present a degree of correlation which is very slight, and render im-
possible any real comparison with the corresponding parts in the
shrimp, for instance, which has scarcely any rostrum at all.

Selection was made of the female prawn as being larger than the
male, and therefore more convenient for the purposes of measure-
ment.   The largest measured 111 mm. in total body length, the
smallest 61·5 mm.

All the measurements having been reduced, as above stated, to
fractions of the total body length, they were next arranged in order
of magnitude for each organ separately, and in almost every case the
values were found to range themselves with a fair degree of symmetry
around the median value, and to correspond with more or less
accuracy to calculated probability curves.   In one case, however
(measurement No. VII), the curve presented features of asymmetry
which have been investigated by Professor Karl Pearson ('Roy. Soc.
Proc.,' vol. 54, p. 329).

The next step was to determine the degree of correlation between
various pairs of the organs measured.   The method used was that
originally suggested by Mr. Galton, and sufficiently explained by
Professor Weldon in his paper above referred to, so that it is un-
necessary to repeat it here.

The following table gives the value of " Galton's function " for 56
pairs of organs :—

Values of Galton's Function (*r*) for Pairs of Organs in the Common Prawn.

(The Roman numerals refer to the list of organs measured given above.)

Pairs of organs.		Value of *r*.	Pairs of organs.		Value of *r*.
II and	IV	−0·30	X and	XI	0·61
II „	V	−0·34	X „	XII	0·58
II „	VI	—	X „	XIII	0·55
II „	VII	0·20	X „	XIV	0·55
II „	VIII	0·59	X „	XV	0·55
II „	IX*a*	0·30	X „	XVI	0·51
II „	X	0·54	X „	XVII	0·28
II „	XII	0·45	XII „	XIII	0·70
II „	XIII	0·54	XII „	XIV	0·56
II „	XIV	0·46	XII „	XV	0·56
II „	XV	0·54	XII „	XVI	0·47
II „	XVI	0·59	XII „	XVII	0·26
II „	XVII	0·40	XIII „	XIV	0·71
II „	XVIII*a*	0·46	XIII „	XV	0·61
IV „	VIII	−0·18	XIII „	XVI	0·60
V „	VIII	−0·40	XIII „	XVII	0·28
VI „	VIII	−0·16	XIV „	XV	0·62
VII „	VIII	−0·08	XIV „	XVI	0·54
VIII „	IX*a*	0·27	XIV „	XVII	0·26
VIII „	X	0·37	XV „	XVI	0·57
VIII „	XII	0·37	XV „	XVII	0·29
VIII „	XIII	0·34	XVI „	XVII	0·51
VIII „	XIV	0·26	XVI „	XVIII*a*	0·43
VIII „	XV	0·32	XVI „	XVIII*b*	0·49
VIII „	XVI	0·39	XVII „	XVIII*a*	0·68
VIII „	XVII	0·31	XVII „	XIX*a*	0·15
VIII „	XVIII*a*	0·33	XVIII*a* „	XVIII*b*	0·86
IX*a* „	IX*b*	0·94	XIX*a* „	XIX*b*	0·76

An examination of these values shows that, as might be expected, the highest degree of correlation exists between the paired organs, viz., between the right and left squames, 0·94; between the right and left exopodites of the 6th pair of swimmerets, which, with the telson, form the propelling organ of the prawn, 0·86; between the distances of the spines on the telson from its posterior end, 0·76.

Next, we observe that a strong correlation obtains between the terga of adjacent abdominal segments; their values range between 0·58 and 0·71; while those of segments that do not lie next each other range between 0·47 and 0·61. A considerable fall occurs in the degree of correlation between the telson and the segments of the abdomen—it varies from 0·26 to 0·29, except in the case of the 6th abdominal segment, which lies next to the telson, when the value rises to 0·51. It is interesting to note that Professor Weldon found the corresponding value for the telson and 6th abdominal tergum in the

common shrimp from Plymouth to be only 0·11. Perhaps this difference may in part be accounted for by the fact that the prawn is essentially a swimmer, while the shrimp, in confinement at any rate, spends most of its time standing or crawling on the surface of the sea-bottom. The prawn is certainly a more powerful and rapid swimmer. It swims backwards, propelling itself by means of the hinder part of the abdomen, the terminal portion of which is fan-shaped, the fan consisting of the telson and the exopodites of the last pair of appendages. This hinder half of the abdomen starts from the extended position, and is brought, with a rapid stroke, up under the fore part of the abdomen and thorax, pushing the water before it, and so propelling the animal backwards. The 3rd segment acts as the hinge of the propeller, and it may be assumed that the exoskeleton is here exposed to the greatest strain, for here we find the highest degree of correlation, as is shown by the following figures :—

Index of correlation between terga of abdominal segments 1 and 2 = 0·58.

,,   ,,   ,,   2 ,, 3 = 0·70.

,,   ,,   ,   ,,   3 ,, 4 = 0·71.

,,   ,,   ,,   4 ,, 5 = 0·62.

,,   ,,   ,,   5 ,, 6 = 0·57.

,,   ,,   ,,   6 and

                                                    telson = 0·51.

Professor Weldon determined three other values in the shrimp, viz., the relations between carapace length and post-spinous portion of carapace, between carapace length and tergum of abdomen vi., and between carapace length and telson. Their values were (in Plymouth specimens) 0·81, 0·09, and 0·18 respectively. It is not possible to institute a comparison with exactly the same organs in the prawn, as, owing to the great variation in the length of the rostrum, no appreciable degree of correlation exists between the whole carapace including rostrum (measurement No. III) and the other organs. But if we take measurement No. II (from orbit to hinder edge of carapace) as an approximate equivalent to the carapace measurements of the shrimp, we find in the prawn the corresponding values are 0·59, 0·59, and 0·40. The difference in the first measurement, viz., shrimp, 0·81 ; prawn, 0·59, may be accounted for by the fact that the dorsal spines probably do not correspond in nature or function in the two animals. The shrimp has but one median dorsal spine, situated far forward ; the prawn has a row of them.

But why the prawn should exhibit a so much higher degree of correlation between the carapace and the two terminal segments of its body than the shrimp is not, I think, readily to be ex-

plained at first sight, unless it be due to difference in habits of locomotion above referred to.

The subjoined table furnishes the necessary data for constructing approximately the curve of each of the separate organs.

The Roman numerals in the first column refer to the organ described above under the corresponding numbers on p. 235; the second column contains the number of animals out of the whole sample of 1000 in which a measurement of the particular organ was made; the third column contains the median value; and the fourth the "probable error" or quartile deviation from the median of each organ expressed in thousandths of the body length; the fifth and sixth columns refer to the same animals after subtracting from their number thirteen individuals in which the rostrum or telson was deformed, and for these the arithmetical mean and probable error (obtained by finding the mean error and multiplying it by 0·845) are given.

All the figures in columns 3 to 6, inclusive, represent thousandths of the body length, except those standing against organ No. I (the body length itself), which represent millimetres.

No. of organ.	Sample of 1000.			Ditto less 13 deformed.	
	No. of animals measured.	Median.	Q.	Arith. mean.	Probable error.
I	1000	88·03	4·85	88·20	4·91
II	1000	200·40	3·46	200·43	3·49
III	1000	462·20	7·19	462·56	7·26
IV	1000	130·31	9·83	129·84	10·46
V	998	306·88	8·18	306·95	8·12
VI	998	179·39	8·16	180·39	9·02
VII	998	42·94	2·39	43·11	2·34
VIII	997	155·01	3·66	155·02	3·78
IXa	976	159·70	8·29	160·04	3·28
IXb	967	160·98	3·26	160·58	3·24
X	863	83·98	1·79	83·91	1·77
XI	999	42·37	1·19	42·21	1·17
XII	1000	101·49	2·08	101·40	2·12
XIII	1000	134·72	2·52	134·69	2·55
XIV	999	114·14	2·37	113·97	2·33
XV	997	77·32	1·61	77·22	1·63
XVI	992	112·39	2·19	112·30	2·26
XVII	998	134·82	2·65	134·83	2·61
XVIIIa	971	120·84	2·25	120·88	2·21
XVIIIb	719	120·73	2·36	120·70	2·31
XIXa	571	33·33	2·55	33·33	2·73
XIXb	572	33·25	2·46	33·27	2·59

In conclusion, I desire to express my warm thanks to Professor Weldon for constant advice and assistance on many points connected with the preparation of the foregoing data.

Presents, March 1, 1894.

Transactions.

Baltimore :—Johns Hopkins University. Circulars. Vol. XIII. No. 109. 4to. *Baltimore* 1894. The University.

Béziers :—Société d'Étude des Sciences Naturelles. Bulletin. Vol. XV. 8vo. *Béziers* 1893. The Society.

Bordeaux :—Société de Médecine et de Chirurgie. Mémoires et Bulletins. 1892. Fasc. 3—4. 8vo. *Bordeaux* 1893.
The Society.

Cracow :—Académie des Sciences. Bulletin International. Janvier, 1894. 8vo. *Cracovie.* The Academy.

Freiburg i. B. :—Naturforschende Gesellschaft. Berichte. Bd. VIII. 8vo. *Freiburg i. B.* 1894. The Society.

Genoa :—Società Ligustica di Scienze Naturali e Geografiche. Atti. Vol. IV. Nos. 2—3. 8vo. *Genova* 1893.
The Society.

Kingston :—Institute of Jamaica. Journal. Vol. I. No. 8. 8vo. *Kingston* 1893. The Institute.

London :—British Museum. Catalogue of the Birds. Vol. XXII. 8vo. *London* 1893. The Trustees.

Institute of Brewing. Transactions. Vol. VII. Nos. 3—4. 8vo. *London* 1894. The Institute.

Royal Horticultural Society. Journal. Vol. XVI. Parts 2—3. 8vo. *London* 1894. The Society.

Royal Meteorological Society. Quarterly Journal. Vol. XX. No. 89. 8vo. *London* 1894; The Meteorological Record. Vol. XIII. No. 50. 8vo. *London.* The Society.

Royal United Service Institution. Journal. Vol. XXXVIII. No. 192. 8vo. *London* 1894. The Institution.

Lyons .—Université. Annales. Tome VI. Fasc. 3. 8vo. *Lyon* 1893. The University.

Marseilles :—Faculté des Sciences. Annales. Tome III. Fasc. 1—3. 4to. *Marseille* 1893. The Faculty.

Melbourne :—Royal Society of Victoria. Proceedings. Vol. VI. 8vo. *Melbourne* 1894. The Society.

Mexico :—Sociedad Científica " Antonio Alzate." Memorias y Revista. Tomo VII. Nos. 5—6. 8vo. *México* 1893.
The Society.

Montpellier :—Académie des Sciences et Lettres. Mémoires. Section des Sciences. 2e Série. Tome I. Nos. 1—2. 8vo.

Transactions (*continued*).

    Montpellier 1893; Section de Médecine. 2e Série. Tome I.
    No. 1. 8vo. *Montpellier* 1893; Section des Lettres. 2 ›
    Série. Tome 1. Nos. 1—3. 8vo. *Montpellier* 1893.
                                        The Academy.

New York:—American Museum of Natural History. Bulletin.
    Vol. VI. Pages 1—32. 8vo. [*New York*] 1894.
                                          The Museum.

Palermo:—Circolo Matematico. Rendiconti. Tomo VII. Fasc. 6.
    8vo. *Palermo* 1893.   The Circle.

Paris:—Comité International des Poids et Mesures. Seizième
    Rapport. Folio. *Paris* 1893; Travaux et Mémoires du
    Bureau International des Poids et Mesures. Tome VIII.
    Folio. *Paris* 1893.   The Committee.

    École des Hautes Études. Bibliothèque. Fasc. 98. 8vo. *Paris*
    1893.   The School.

    École Polytechnique. Journal. Cahier LXIII. 4to. *Paris* 1893.
                                        The School.

    Société d'Encouragement pour l'Industrie Nationale. Annuaire.
    1894. 8vo. *Paris* 1894.   The Society.

    Société Entomologique de France. Annales. Vol. LXI. 8vo.
    Paris 1892–93.   The Society.

    Société Géologique de France. Bulletin. Tome XX. Nos. 6—8.
    Tome XXI. Nos. 1—3. 8vo. *Paris* 1893.   The Society.

Rome:—R. Accademia dei Lincei. Annuario 1894. 8vo. *Roma*
    1894.   The Academy.

Siena:—R. Accademia dei Fisiocritici. Atti. Vol. V. Fasc. 9—
    10. 8vo. *Siena* 1894.   The Academy.

Stockholm:—Kongl. Vetenskaps Akademie. Öfversigt. Årg. L.
    No. 10. 8vo. *Stockholm* 1894.   The Academy.

Topeka:—Kansas Academy of Sciences. Transactions. Vol.
    XIII. 8vo. *Topeka* 1893.   The Academy.

Turin:—R. Accademia delle Scienze. Atti. Vol. XXIX. Disp.
    1—4. 8vo. *Torino* [1893–94].   The Academy.

Vienna:—Anthropologische Gesellschaft. Mittheilungen. Bd.
    XXIII. Heft 6. 4to. *Wien* 1893.   The Society.

Washington:—U.S. Department of Agriculture. Experiment Sta-
    tion Bulletin. No. 18. 8vo. *Washington* 1894.
                                       The Department.

Wellington, N.Z.:—Polynesian Society. Journal. Vol. II. No. 4.
    8vo. *Wellington* 1893.   The Society.

Zurich:—Naturforschende Gesellschaft. Neujahrsblatt. No. 96.
    4to. *Zürich* 1893; Vierteljahrsschrift. Jahrg. XXXVIII.
    Heft 3—4. 8vo. *Zürich* 1893.   The Society.

Observations and Reports.

Albany:—New York State Library. Annual Report. 73—75. 8vo. *Albany* 1891—93: State Library Bulletin: Legislation. No. 4. 8vo. *Albany* 1894. The Library.

Berlin:—Königl. Sternwarte. Berliner Astronomisches Jahrbuch. 1896. 8vo. *Berlin* 1894. The Observatory.

India:—Census of India, 1891. General Report, by J. A. Baines. Folio. *London* 1893; General Tables for British Provinces and Feudatory States. Vols. I—II. Folio. *London* 1892-93. The India Office.

London:—Admiralty. List of Oceanic Depths and Serial Temperature Observations received at the Admiralty during the year 1893. Folio. *London* 1894. The Hydrographer.

Marseilles:—Commission de Météorologie du Département des Bouches-du-Rhône. Bulletin Annuel. Année 1892. 4to. *Marseille* 1893. The Commission.

Paris:—Bureau Central Météorologique. Annales. Année 1891. 4to. *Paris* 1893; Rapport de la Conférence Météorologique Internationale: Réunion de Munich, 1891. 8vo. *Paris* 1893. The Bureau.

Observatoire. Annales: Observations. 1885. 4to. *Paris* 1893. The Observatory.

Stonyhurst:—Stonyhurst College Observatory. Results of Meteorological, Magnetical, and Solar Observations. 1893. 8vo. *Clitheroe* 1894. Rev. W. Sidgreaves, S.J.

Sydney:—Observatory. Meteorological Observations. August, 1893. 8vo. [*Sydney.*] The Observatory.

United States:—U.S. Coast and Geodetic Survey. Bulletin. Nos. 28—30. 8vo. *Washington* 1893. The Survey.

Journals.

Boletin de Minas Industria y Construcciones. Tome IX. Num. 11. 4to. *Lima* 1893. Escuela Especial de Ingenieros, Lima.

Zeitschrift für Biologie. Bd. XXX. Heft 3. 8vo. *München* 1894. The Editors.

Crouch (W.) Astronomy in Wanstead: a Chapter of its Past History. 8vo. [1893.] The Author.

Mohorovičić (A.) Der Tornado bei Novska. 8vo. *Agram* 1894. The Author.

[Pasteur (L.)] Jubilé de M. Pasteur. 1822—1892. 4to. *Paris* 1893. Comité du Jubilé Pasteur.

Rietschel (H.) Der Stand der wissenschaftlichen und praktischen Wohnungs-Hygiene in Beziehung zur Luft: Rede. 4to. *Berlin* 1894. K. Technische Hochschule, Berlin

Taw Sien-Ko. A Preliminary Study of the Kalyani Inscriptions of Dbammacheti. 1476 A.D. 4to. *Bombay* 1893.

Department of Revenue and Agriculture, Calcutta.

March 8, 1894.

Sir JOHN LUBBOCK, Vice-President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The Croonian Lecture was delivered as follows :—

CROONIAN LECTURE.—" La fine Structure des Centres Nerveux." By S. RAMÓN Y CAJAL, Professor of Physiology in the University of Madrid. Received March 1, 1894.

[Publication deferred.]

Presents, March 8, 1894.

Transactions.

Batavia :—Bataviaasch Genootschap van Kunsten en Weten-schappen. Notulen. Deel XXXI. Aflev. 1—2. 8vo. *Batavia* 1893 ; Tijdschrift voor Indische Taal-, Land- en Volkenkunde. Deel XXXVI. Aflev. 4—6. 8vo. *Batavia* 1893. The Society.

Buitenzorg :—'s Lands Plantentuin. Verslag. 1892. 8vo. *Batavia* 1894. The Director.

Gloucester :—Cotteswold Naturalists' Field Club. Proceedings. Vol. XI. Part 1. 8vo. *Gloucester* [1894]. The Club.

Heidelberg :—Naturhistorisch-medicinischer Verein. Verhand-lungen. Bd. V. Heft 2. 8vo. *Heidelberg* 1894. The Society.

Lausanne :—Société Vaudoise des Sciences Naturelles. Bulletin Vol. XXIX. No. 113. 8vo. *Lausanne* 1893. The Society.

London :—British Astronomical Association. Journal. Vol. IV. No. 3. 8vo. *London* 1894, The Association.

East India Association. Journal. Vol. XXVI. No. 3. 8vo. *London* 1894. The Association.

Geologists' Association. List of Members. 1894. 8vo. *London*. The Association.

Transactions (*continued*).

> Iron and Steel Institute. Journal. Vol. XLIV. 8vo. *London* 1894.　　　　　　　　　　　　　　　· The Institute.
>
> Photographic Society of Great Britain. Journal and Transactions. Vol. XVIII. No. 6. 8vo. *London* 1894.
>
> 　　　　　　　　　　　　　　　　　The Society.
>
> Royal Microscopical Society. Journal. 1894. Part 1. 8vo. *London.*　　　　　　　　　　　　　　　The Society.
>
> Saint Bartholomew's Hospital. Reports. Vol. XXIX. 8vo. *London* 1893.　　　　　　　　　　　　　The Hospital.
>
> Madison :—Wisconsin Academy of Sciences, Arts, and Letters. Transactions. Vol. IX. Part 2. 8vo. *Madison* 1893.
>
> 　　　　　　　　　　　　　　　　　The Academy.
>
> New York :—American Museum of Natural History. Bulletin. Vol. V. Vol. VI. Pp. 33—80. 8vo. *New York* 1893-94.
>
> 　　　　　　　　　　　　　　　　　The Museum.
>
> Rome :—R. Comitato Geologico d'Italia. Bollettino. Vol. XXIV. Trim. 4. 8vo. *Roma* 1893.　　　　　The Committee.
>
> Washington :—National Academy of Sciences. Memoirs. Vol. VI. 4to. *Washington* 1893.　　　　　The Academy.

Observations and Reports.

> Hobart :—Office of the Government Statistician. Statistics of the Colony of Tasmania. 1892. Folio. *Hobart* 1893.
>
> 　　　　　　　　　　　　The Government Statistician.
>
> India :—Botanical Survey. Records. Vol. I. Nos. 1—2. 8vo. *Calcutta* 1893-94.　　　　　　　　The Survey.
>
> Geological Survey. Records. Vol. XXVI. Part 4. 8vo. *Calcutta* 1893.　　　　　　　　　　The Survey.
>
> Montpellier :—Commission Météorologique de l' Hérault. Bulletin Météorologique. Année 1892. 4to. *Montpellier* 1892.
>
> 　　　　　　　　　　　　　　　　　The Commission.
>
> San Fernando :—Instituto y Observatorio de Marina. Observaciones Meteorológicas y Magnéticas. Año 1892. 4to. *San Fernando* 1893.　　　　　　　　　　　　The Institute.
>
> Spain :—Comisión del Mapa Geológico. Boletin. Tomo XIX. 8vo. *Madrid* 1893.　　　　　　　　The Commission.

Journals.

> Agricultural Gazette of New South Wales. Vol. IV. Part 12. 8vo. *Sydney* 1893.　　　Department of Agriculture, Sydney.
>
> Horological Journal. Vol. XXXVI. No. 427. 8vo. *London* 1894.　　　　　　　　British Horological Institute.

Journals (*continued*).

 Journal of Comparative Neurology. September, 1893. 8vo. *Granville, Ohio.*
                The Editor.

 Stazioni Sperimentali Agrarie Italiane. Vol. XXVI. Fasc. 1.
  8vo. *Modena* 1894. ·   R. Stazione Agraria, Modena.

Akerblom (Ph.) De l'Emploi des Photogrammètres pour mesurer
 la Hauteur des Nuages. 8vo. *Upsala* 1894.
         Meteorological Observatory, Upsala.

Basset (A. B.), F.R.S. [Volume of Excerpts lettered "Mathematical Papers, 1882–92."] 8vo.   The Author.

Bickerton (A. W.) A New Story of the Stars. 8vo. *Christchurch,
 N.Z.* 1894.   The Author.

Chijs (J. A. van der.) Dagh-Register gehouden int Casteel Batavia
 vant passerende daer ter plaetse als over geheel Nederlandts-
 India. Anno 1664. 8vo. *Batavia* 1893 ; Nederlandsch-Indisch
 Plakaatboek, 1602–1811. Deel XI. 8vo. *Batavia* 1893.
    Bataviaasch Genootschap van Kunsten en Wetenschappen.

Liversidge (A.), F.R.S. On the Origin of Moss Gold. [And other
 Papers.] 8vo. [*Sydney* 1893.]   The Author.

Macfarlane (A.) On the Definitions of Trigonometric Functions.
 8vo. *Boston* 1894.   The Author.

Packard (A. S.) Further Studies on the Brain of *Limulus Poly-
 phemus*, with Notes on its Embryology. 4to. [*Washington*
 1893.]   The Author.

March 15, 1894.

The LORD KELVIN, D.C.L., LL.D., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read :—

I. "The Thermal Radiation from Sun Spots. Preliminary Notes of Observations made at Daramona, Streete, Co. Westmeath, 1893." By W. E. WILSON, M.R.I.A. Communicated by G. JOHNSTONE STONEY, F.R.S. Received January 4, 1894.

These observations were made by means of a large heliostat, lent by the Royal Society, and a Boys's radio-micrometer. The heliostat consists of a plane silver-on-glass mirror of 15 in. aperture. It is mounted equatorially, and driven by a clock. When in use, it is adjusted to reflect the sunlight to the north pole, and, as long as the driving clock is kept in motion, the beam of light remains fixed in that position. In the track of this beam, and about 12 ft. from the plane mirror, is mounted a concave silver-on-glass mirror of 9 in. aperture, and about 13 ft. focus. Its axis points to the south pole, so that the cone of rays formed by it strikes the centre of the plane mirror, and a short distance inside the focus. A small plane mirror mounted on the end of an arm is then so placed as to intercept the cone of rays, and reflect it horizontally into the observatory window ; an achromatic lens enlarges the solar image which is formed on a screen in the room to 4 ft. in diameter.

Behind this screen, and standing on a pier of concrete, is mounted the radio-micrometer. The aperture through which radiant heat reaches the sensitive thermo-couple is a round hole drilled through a thick sheet of brass, and is only 1 mm. in diameter. A white cardboard screen is placed in front of the brass one to cut off heat from falling on the latter, and is provided with a hole slightly larger. A beam of lime light is thrown on the mirror of the radio-micrometer, and reflected on to the scale in the usual way. The diagonal mirror of the heliostat is provided with slow motions in two directions, which are moved by long rods and Hook joints inside the observatory. Thus any part of the sun's disc can be placed on the small aperture

of the radio-micrometer, and the driving clock will then keep it there.

The observations are taken in the following manner. A small screen is placed over the aperture of the radio-micrometer, and the zero position of the spot of light on the scale noted. The screen is then removed, and the umbra of a sun spot placed on the aperture. The reading is then taken and entered in column *u*. The image is then moved, so that a part in the neighbourhood of the spot, but at *the same distance from the centre of the solar disc*, is placed on the aperture. This reading is entered in column N. Finally, a reading is taken at the centre of the disc, and entered in column C. The throws of the instrument are then got by subtracting the figures in columns *u*, N, and C from the zero. The deflections of the instrument have been experimentally proved to be *strictly proportional* to the amount of radiant heat falling on the thermo-couple. The following is a typical observation taken August 7, 1893, of a large sun spot then visible. The *umbra* of this spot measured 0·8 in. across on the screen, so that the aperture of the radio-micrometer was only covering about $\frac{1}{400}$ of the apparent area of the umbra.

Zero.	*u*.	N.	*u — z.*	N — z.
15·8	17·1	20·4	1·3	4·6
15·6	16·9	20·2	1·3	4·6
15·5	16·8	19·9	1·3	4·4
15·3	16·7	19·8	1·4	4·5
15·2	16·6	19·6	1·4	4·4
15·1	16·4	19·5	1·3	4·4
14·9	16·1	19·4	1·2	4·5
		Means....	1·31	4·49

The ratio $\dfrac{\text{umbra of spot}}{\text{neighbouring photosphere}} = \dfrac{1\cdot31}{4\cdot49} = 0\cdot292.$

Five concordant readings gave a mean deflection of 4·57 for the centre of the sun, which gives for the ratio $\dfrac{\text{umbra}}{\text{centre}} = 0\cdot287.$

This spot was at a distance from the centre of the disc of about 0·4 of the radius.

As the radiation from the photosphere falls off from the centre to the edge of the disc, it seemed an interesting point to determine if any change in the ratio of *u*/C would take place as a spot was carried across the disc by the sun's rotation. If the spot is, as is generally thought, a depression, the absorption of heat ought to increase as it is carried towards the limb, on account of the increased

depth in the solar atmosphere through which the radiation would have to pass. On the other hand, if the spot was floating *above* the absorbing atmosphere the radiation from it would remain constant in any position on the solar disc.

The following is the value of the heat radiation from the photosphere taken along a radius of the sun, where 0 = centre and 100 the limb. The radiation R equals 100 at the centre.[*]

D.	R.
0	100·0
10	99·8
20	99·5
25	99·3
30	98·9
40	97·2
50	95·3
60	92·2
70	87·8
75	85·3
80	82·5
90	72·0
95	61·8
98	51·5
100	42·9

It will be seen by the following observations of spots, taken from August 5 to November 9, that there is distinct evidence that the radiation from the spot does not fall off as rapidly when near the limb as the neighbouring photosphere; in fact, the ratio u/C remains nearly constant, whereas the ratio u/N gets nearer unity as the spot approaches the limb. The spot observed on the 22nd of October is a good example, as the same spot was observed again on the 26th, 29th, and on the 30th, when it had reached within a distance, D, of 95 from the centre. It will be seen that on these four dates the ratio u/C was respectively 0·338, 0·360, 0·313, 0·356, whereas the ratio u/N was 0·349, 0·410, 0·706, 0·783.

Langley,[†] in 1874 and 1875, measured the radiation from sun spots. He used a thermo-pile and galvanometer, and obtained as the mean of his results a ratio of 0·54±0·05.

His method was first to take a reading in the neighbourhood of the spot, but between it and the centre of the disc. He then took a reading in the umbra, and, finally, a third reading in the neighbourhood between the spot and the edge of the sun.

* "The Absorption of Heat in the Solar Atmosphere," by W. E. Wilson and A. A. Rambaut, 'Proceedings of the Royal Irish Academy,' 3rd series, vol. 2, No. 2.
† 'Monthly Notices,' vol. 37, No 1.

Date.	$\frac{u}{C}$.	$\frac{u}{N}$.	D.
1893.			
Aug. 5	0·370	0·427	60
7	0·287	0·292	40
8	0·286	0·323	50
8	0·339	0·377	40
8	0·418	0·512	90
14	0·364	0·373	50
19	0·368	0·375	50
Sept. 2	0·309	0·309	10
3	0·298	0·298	10
4	0·420	0·450	80
4	0·430	0·446	30
7	0·287	0·355	85
Oct. 1	0·398	0·401	80
1	0·489	0·570	80
22	0·338	0·349	52
26	0·360	0·410	40
29	0·313	0·706	90
30	0·356	0·783	95
Nov. 8	0·365	0·800	97
9	0·339	0·848	85

The mean of the two photospheric readings he used as a divisor for the umbral reading. He then says, " The decrement of heat as we approach the limb is, though not exactly, yet so very nearly, in the same ratio for photosphere and spots, that no correction is needed on this account for the present observations."

If Langley failed, through want of instrumental means, to notice the difference between the absorption in a spot and the photosphere near the limb, his method would make his umbral readings too high. The mean of twenty observations here equals 0·356, against Langley's 0·54. This is a serious difference, and, I think, can only be accounted for either by the use of superior instrumental means, or by a possible variation in the radiation of spots in different years of the sun spot cycle.

It is difficult to see how *too low* a value for umbral radiation could be got, whereas too high a one might be found by want of definition and trembling in the image, so that some of the penumbral radiation would reach the thermo-couple.

II. "Experimental Investigations on the Effective Temperature of the Sun, made at Daramona, Streete, Co. Westmeath." By W. E. WILSON, M.R.I.A., and P. L. GRAY, B.Sc., Assoc. R.C.S., Demonstrator of Physics, Mason College, Birmingham. Communicated by G. JOHNSTONE STONEY, F.R.S. Received January 4, 1894.

(Abstract.)

The only tolerably complete series of investigations on this subject up to the present time have been those of Rossetti and Le Châtelier. The results given by other writers have depended more or less on guesses relative to the law connecting radiation and temperature, and differences on this point alone have given values varying between 1500° and 3,000,000° to 5,000,000° C.

Rossetti worked with a thermo-pile, exposed directly to the heat of the sun; the law connecting the deflections of the galvanometer with the temperature of an artificial source of heat having been obtained up to a temperature of *about* 2000° C., from the deflection produced by the heat of the sun the solar temperature was calculated by extrapolation.

Le Châtelier worked on an entirely different principle, measuring the intensity of the light transmitted through a certain piece of red glass, first from sources at known temperatures up to 1700° or 1800°, and, secondly, from the sun, the temperature of which was then obtained, as in Rossetti's case, by a process of extra-polation, which is, of course, necessary in any method, until we can raise substances to a temperature actually as high as that of the sun, an experiment at present impossible.

Rossetti obtained finally a temperature of 10,000° C., approximately, while Le Châtelier gives 7600° ($\pm$ 1000°) as the mean of his results. In the paper the difference between Rossetti's result and our own (6200° C.) is discussed, and a possible explanation given.

The method adopted by the authors is a zero method, and the essential point is the *balancing* of the heat from the sun with that from a platinum strip heated to a high known temperature.

The artificial source of heat was a modified form of Joly's "meldometer," the calibration of which can be performed with a very high degree of accuracy. The "radiation balance" is a form of Boys's radio-micrometer containing a duplex circuit, so designed that the heat from the sun can be made to exert a turning moment in the opposite direction to that due to the artificial source of heat, and by making the apparent area of the latter sufficiently great, the radia-

tion from it may be increased so far as to equal that arriving at the radio-micrometer from the sun.

The following points are considered, after descriptions of the method and apparatus have been given :—

1. The law connecting radiation and temperature.

>This is probably the most important factor in the value of the final result. Numerous investigations on the point have been made, which are referred to in the paper.

>After a careful series of experiments we have come to the conclusion that (at least for bright platinum) Stefan's "law of the 4th power" holds,[*] *i.e.*, that for high temperatures (say over 600° or 700° C.) if R = the radiation from a source whose absolute temperature is T, then

$$R \propto T^4.$$

2. The emissive power of platinum at high temperatures compared with that of lamp-black.

>On this point the value obtained by Rossetti was used, some considerations being given in support of his figures.

3. The amount of the atmospheric absorption.

>This is fully discussed, and again the value obtained by Rossetti is used.

>Langley's theoretical value for percentage absorption of radiation from a body in the zenith, viz., 41 per cent., is shown to be possibly too great; Rossetti obtained 29 per cent., which appears to be the value best supported by experiment.

>The climate of Ireland entirely prevents a systematic series of investigations on this particular point.

Several subsidiary questions are also discussed, and, finally, the results of about sixty-nine observations are given, which lead to a final mean result for the *effective* solar temperature of 6200° C.

It is pointed out, in conclusion, that the method would probably give excellent results if adopted in some country in or near the tropics, where atmospheric conditions can be trusted to remain more constant for some weeks, or even days, together, and where a series of observations taken at the same part of the year throughout the period of a sun-spot cycle might be hoped to settle the question of how (or if) the solar temperature varies during this time, as any error in the absolute value obtained may probably be considered constant, so that comparative values from year to year might be trusted to indicate any change.

---

[*] Stefan, however, stated the law as applying to the "pure" radiation of a surface of perfect emissive power.

III. "Experiments on a Fundamental Question in Electro-Optics: Reduction of Relative Retardations to Absolute." By JOHN KERR, LL.D., F.R.S.   Received March 9, 1894.

To prepare the way, I begin by recalling these well-known facts: that when light passes through an electrostatically strained medium in a direction perpendicular to the line of electric force, it undergoes a uni-axal double refraction, thé optic axis coinciding with the line of force; that with reference to this action, dielectrics are divisible into two classes, the positive[*] and the negative,[†] which are optically related to each other in the same way as the positive class of crystals to the negative; that the intensity of the action, or the quantity of optical effect per unit thickness of the dielectric, is measured by the product CP^2, where C is a constant which is characteristic of the medium, and P is the value of the resultant electric force : that the effects are generally observed and examined still as they were discovered first, by simple experiments with a pair of Nicol's prisms and a slip of strained glass or other phase-difference compensator.

In every such experiment the effect specified by the compensator is a difference of phases, or a relative retardation ; and we may therefore view it as a resultant effect—that is to say, as the resultant, or the difference, of electrically-generated absolute retardations of two component lights, whose planes of polarisation are parallel and perpendicular to the line of electric force. What, then, are the values of these two absolute retardations in any given case? *What are the two absolute components of any electrically-generated relative retardation?* Such is the question here proposed for solution by experiment.

As long ago as 1882, and several years following, I was much occupied at intervals with this interesting question. In the summer of 1885, in some experiments with the dielectric CS_2, I obtained results as decisive as could be desired. Other dielectrics, both solid and liquid, were tried afterwards, but only with partial success, the experimental difficulties being, in some cases, too much for my methods and time. To these cases I shall make no further reference, as I will keep to the one line of experiment, and to those experiments in particular in which the indications were quite regular and unmistakeable. With these limitations, the inductions extend to four liquid dielectrics, two positive and two negative; and all the experiments point clearly in one direction.

General Result.—It appears that the proper and immediate optical

[*] Carbon disulphide, the hydrocarbons, &c.
[†] Amyl oxide, the heavy oils, &c.

effect of electric strain is a positive or negative retardation of the one component light whose plane of polarisation is perpendicular to the line of force, the sign of the retardation being, of course, the same as the nominal sign of the dielectric. Therefore, of two vibrations which are (on Fresnel's hypothesis) perpendicular and parallel respectively to the line of force, it is only the latter that is immediately affected by the electric strain, this *vibration along the line of force* having its velocity of transmission *retarded* or *accelerated* according as the dielectric is of the *positive* class or the *negative*.

I venture to regard this result as a general law of double refraction in electro-optics, though the proof extends only to four different dielectrics. As the best proof that I can offer, I will merely give a condensed historical sketch of the experiments. It will be seen in this way how the law was first suggested and then confirmed by the phases of a new electro-optic effect. It will be seen also that the proof of the law is independent of all hypotheses, independent even of everything previously known in electro-optics.

The Plate Cell is a piece used in all the experiments. There is an

Fig 1.

end-view of it given in the adjacent figure. It consists of five slabs of plate glass, each 10 in. by 7¾ in., arranged face to face in one block. The inner rectangle represents a tunnel (5¾ in. by 3¼ in.) which passes right through the block. Inside are shown the conductors with supporting frame, the shaded pieces being of brass, and the unshaded of plate glass. The lengths of the conductors, at right angles to the plane of the figure (and parallel to the light), are 6¼ in. and 7½ in., the thickness of the cell being nearly 8 in. By means of wires, which pass through the wall of the cell, the internal conductors are con-

nected with prime conductor and earth, as indicated in the figure. It is understood, of course, that the surfaces of the two conductors are well planed and polished, all corners and edges rounded off, and the two fronting faces accurately parallel. The cell is closed, in the usual way, by panes of plate glass laid against the ends, and the whole block is kept together by a screw-press. Two borings in one of the plates provide for the filling and emptying. When the cell is put in order and charged with CS_2, and examined according to the old method (with a pair of crossed nicols), it gives a very pure double refraction, and acts well in all respects, except that (from deficiency of insulation) the largest effect is less than might be expected, hardly amounting to one average wave-length of relative retardation. But this defect is of no great consequence.

The First Experimental Arrangement is shown in the next diagram, in horizontal section through the lamp L and the observer's eye E, but without strict regard to scale.

Fig 2

Two $\frac{1}{2}$-in. plates of glass are represented in section by the rectangles PQ, RS. Their function is the same as that of the two plates in Jamin's interference refractometer.* The plates are, therefore, parallel-surfaced, and of accurately equal thickness, and are silvered on the back as mirrors; and in their working positions they are almost exactly vertical and parallel, and at 45° to the light. A pencil of light, LB, which passes through a vertical slit in front of the lamp, is incident on the first plate at B, and is divided, in the manner shown in the diagram, into two pencils, BDCG and BFHG; and from G the light proceeds anew as one pencil, and passes through a narrow circular diaphragm,† which is fixed at E in front of the observer's eye.

* Preston's 'Theory of Light,' p. 157.
† Or, otherwise, through a telescope.

The result of the arrangement is that, when the pieces are properly placed, the bright vertical slit L, as seen from E in the direction EG, is crossed by a set of interference-fringes. These are well defined in position by reference to a constant black line, the image of a fine wire which is fixed across the slit L. It may be assumed, without argument, that any small increase or decrease of velocity of one of the pencils BF, CG, will produce a positive or negative displacement of the fringes, at the rate of one fringe-width of displacement for every wave-length of relative retardation. As far as the assumption is required, it is easily verified by the introduction of thin plates of glass into the course of the light, anywhere between the two thick plates ; and I find in this way, definitely, that (as the pieces actually stand in the diagram and in all the experiments) an ascent of the fringes indicates a relative retardation of the pencil BF.

There are two essential pieces that remain to be noticed, of which the first is the electro-optic cell. It is shown in the diagram how the laterally separated component pencils pass through the cell, BF through the electric field, and CG through the space electrically screened by the second conductor, this conductor being always to earth. The last piece is a Nicol's prism N, which is placed in the path of either of the single pencils GE, LB, with its principal section laid (1) horizontally and (2) vertically. The design of the apparatus will now be apparent, which is to give the means of detecting electrically generated changes of velocity of the light BF in two successive cases, when the plane of polarisation is (1) perpendicular to the lines of force, and (2) parallel to the lines of force. But in actual experiment there is a difficulty encountered at once, which appears at first sight to be insurmountable.

Disturbance of the Fringes.—Suppose all the pieces placed as in the diagram, the cell nearly filled with carbon disulphide, the second internal conductor put permanently to earth, and the fringes obtained in good form and position. When connexion is made between the first internal conductor and the knob of a charged Leyden jar whose outer coating is to earth, there is an immediate disturbance of the fringes, a set of large and irregular movements, with deformations, ending in the disappearance of the whole system in one or two seconds. The effects are seen better when the first internal conductor is connected permanently with the prime conductor and an attached Leyden jar, for the potential can then be raised regularly and very slowly from zero, and the full course of the disturbance takes a longer time ; but in other respects the phenomena are the same as before.

When the fringes have been extinguished in this way by the electric action, it is easy to recover them, either by putting the prime conductor to earth, or by keeping the potential at a sensibly constant

value, high or low, for a little time. If with this view the machine be kept working at a constant rate throughout the experiment, the extinguished fringes return gradually into the optical field, and in a little time (twenty to eighty turns of the plate) they are as clearly visible as they were before disturbance; their forms also are good, and their positions approximately constant, though they do not often continue quite motionless in such circumstances, even for a fraction of a second. If the prime conductor be now put to earth for a little, and the experiment be then repeated, the disturbance passes through all the same phases as formerly, though it is more violent at starting as the preceding interval of rest is longer. All these effects come out equally well with common light, and with light polarised in the two principal planes.

This optical disturbance is evidently a remote effect of the electric action, produced immediately—not by electric strain—but by irregular changes of density in the medium. We know that in the present cell, as in every like arrangement, the electric action throws the liquid into currents, which pervade all parts of the cell and are very intense at high potential. These material currents explain the changes of density; for, at starting, they give rise to a rapid process of mixture, forcing denser masses upward into the course of the light, &c., and, afterwards, when the mixture is completed, they are still accompanied by irregular variations of pressure in the liquid. It should be easy, therefore, to imitate the effects by means purely mechanical; and of this I can give an example from actual observation.

A plate cell, about an inch thick and open at the top, was charged with water, and placed in the course of the pencils BF, CG, immediately behind the electro-optic cell; and the fringes were obtained in good form and position. The stirring of this water gave a set of optical effects that could not be distinguished from the former disturbance. And when the fringes, extinguished in this way mechanically, were well restored and made moderately steady by regular stirring kept up for a time, I found that a disturbance of the same kind could be obtained at pleasure, either by an interval of rest (the longer the better), or by the addition of a little warm water. But leaving this and returning to the electro-optic experiments, I proceed to show how, in spite of these irregular movements of the fringes, and in the midst of them all, it is possible to obtain a steady effect, which corresponds perfectly to the known bi-refringent action of the medium.

Regular Dislocation of the Fringes.—The electric arrangements are the same as formerly, the two internal conductors being connected permanently, the first with the prime conductor, and the second with earth. There is only one change made in the apparatus; the nicol

N is withdrawn, and a small rhomb of Iceland spar (about 3 cm. long) is put in its place at E, with principal section horizontal. In this way the two systems of fringes which were given by the nicol N in succession are now given simultaneously, side by side, and each the exact prolongation of the other; the successive systems (α) of the next diagram are changed into the double system (β, γ).

The machine is now set in motion. The system (β, γ) is disturbed as was the system (α) formerly; but in the midst of the disturbance, and as long as the fringes are clearly visible, the sets (β) and (γ) are

Fig 3.

seen to be relatively displaced, the system (β, γ) being changed into the system (δ, ϵ). The extent of the dislocation increases as the potential rises; that shown in the diagram, which is about three-fourths of the fringe-width, is not much below the highest that can be got with the apparatus. The direction of the dislocation is constant, and indicates a relative retardation of that vibration in the electric field which is parallel to the line of force; and this agrees with the known character of the medium CS_2 as a positive dielectric.

It is very interesting to watch the two sets of fringes (δ) and (ϵ), and to see them sometimes moving rapidly and very fitfully, but moving always as one system, with its two parts dislocated unchangingly, except so far as the extent of the dislocation varies with varying potential. It is equally interesting to see the effect of spark-discharge of the prime conductor, especially from high potential. At the instant of the spark there is a sudden disappearance of the dislocation, an extremely quick jump of the fringes into line with each other, and this without perceptible check or sudden change of any kind in the disturbance-motion common to the two sets at the time. The best way of observing the effect is to take sparks from prime conductor to earth at stated intervals, while the machine is kept working at some constant rate. The dislocation then

reappears immediately after each of the sparks, increasing regularly from zero as the potential rises, and then increasing and decreasing quickly or slowly as the potential rises and falls quickly or slowly. Even when the potential falls most rapidly, as in spark-discharge, the direction of the backward jump is always evident to the eye; otherwise the disappearance of the dislocation in that case is so very quick that one would call it instantaneous.

Very little need be said upon the optical theory of these phenomena. What must be remembered is, that each of the sets of fringes (δ) and (ϵ) is due to the interference of two such pencils as BF and CG re-united in GE, the vibrations being horizontal in one pair of interfering pencils, and vertical in the other pair. With regard to changes of refringent power which are due to mechanical disturbance, it may be assumed that these are independent of the direction of the vibration: both pairs of pencils are therefore similarly and equally affected at each instant, and the corresponding displacements of the two sets of fringes are at each instant similar and equal, however irregularly they may vary from one instant to another. It is otherwise with the bi-refringent action of the medium; for here the two pairs of pencils are differently affected at each instant, and the difference is determined solely by value of potential, so that the corresponding effect comes out steadily in the midst of all the irregular changes which are produced by mechanical disturbance of the dielectric.

I think it must be admitted that in this regular dislocation of the fringes there is a new and clear presentment of the double refraction which is produced by electric strain. I think also that the new effect is made all the more suggestive by the regularity and perfect steadiness with which it comes out in the midst of the disturbance.

First Appearance of the Law.—Before leaving the present experiments I must notice one or two facts observed, but not yet mentioned, that go towards a solution of the question with which we started. The phenomena to which I refer were seen clearly enough in some of the earlier experiments; but it was only at a later stage that they were well understood, and they were then obtained more regularly.

Beginning with the last form of the experiment—that with the rhomb of Iceland spar as eye-piece. The spar, I should mention, was always so placed that the plane of polarisation in the set of fringes (ϵ) was vertical. What I have to notice now is a peculiar feature of the jump of the fringes at the instant of discharge. To a carefully strained, as to an unstrained, attention, this jump appeared as a movement of the set of fringes (ϵ) down to the level of the set (δ), never as a movement of the set (δ) up to the level of the set (ϵ). I must say, however, that the accuracy of this perception or judgment was to myself in some degree doubtful, not because of any expectation that could have led to it, but because of the very fugitive character

of the phenomenon, and its partial obscuration in many cases by disturbance.
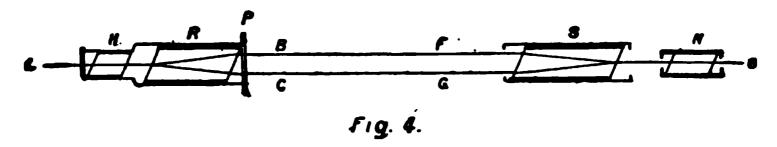
Returning, therefore, to the first form of experiment, that with the nicol N as eye-piece. When the principal section of N was horizontal, and the vibration directed therefore along the line of force, there was a perfectly regular jump of the fringes downwards at the instant of discharge; and at high potential the effect was large and strikingly distinct. When the principal section was vertical, there was nothing regular of this kind seen in any of a large number of observations : there were disturbance-movements at or about the instant of discharge, as before and after, but nothing that could be accepted as a regular jump of the fringes at that instant, always in one direction or always in the other. The interpretation of these results is obvious. I have already stated, as a matter of observation, that a rise of the fringes indicates a relative retardation of the pencil BF which passes through the electric field. From the downward jump of the fringes in one of the two cases, we infer therefore that the pencil BF is in that case relatively accelerated in consequence of discharge. But in the present experiment, and with reference to the pencil BF in relation to the pencil CG, it is evident that relative acceleration and absolute are equivalent; because it is only in that division of the cell through which the pencil BF passes that there is any sudden physical change at the instant of discharge. It appears, therefore, that to relieve the liquid of electric strain, is to relieve one of the vibrations (that along the line of force) of an absolute retardation, leaving the perpendicular vibration unaffected.

In several of the later sets of these experiments with CS_2 as dielectric, and with nicol N as eye-piece, I got what appeared to be a perfectly clean liquid. The potential also was made to vary regularly and very slowly; and from both causes the disturbance was very much reduced. The effects then were these :—Principal section of N horizontal : a slow ascent of the fringes during the process of charge, pretty regular, but often obscured and sometimes overpowered by disturbance; the contrary jump seen always at the instant of discharge. Principal section of N vertical : irregular, and, generally very small oscillations of the fringes during the process of charge; but no regular motion in one direction or the other exclusively, either during the process of charge, or at the instant of spark-discharge from high potential.

From all these experiments with CS_2, it seems to follow that of the two principal vibrations, the only one immediately and regularly affected by electric strain is that along the line of force. This conclusion requires and well deserves to be verified; and I proceed to verify it by another method, or rather by the use of new means.

The Second Experimental Arrangement.—The optical instrument

here used is known as Jamin's Interference Refractor for polarised
light.   For a description of it I might refer to a paper already pub-
lished ;* but I think I ought rather to describe the apparatus here
again.   The essential pieces are shown in horizontal section in the
following diagram.

fig. 4.

R and S are large blocks of Iceland spar, of equal thickness, their
principal sections horizontal, and their faces parallel.   A pencil of
light from a vertical slit L, passes through a Foucault's prism H,
and is polarized by it at 45° to the vertical, and then enters the
rhomb R.   The two pencils emergent from R pass immediately
through a half-wave plate P, so placed as to interchange the two
planes of polarisation.   Ordinary pencil and extra-ordinary in the
crystal R become thus extra-ordinary and ordinary in S, and the bi-re-
fringement action of R is neutralised by that of S.   The light enters
R and leaves S as a single pencil, but between P and S it passes as
a couple of pencils, BF and CG, about 14 mm. apart, and polarised
in planes vertical and horizontal.   The pencil emergent from S is re-
ceived at E through a Nicol's prism N, which is laid as for extinction
with the Foucault H.   When all the pieces have been properly
placed, the slit L is seen crossed by a set of interference-fringes,
and these are modified at pleasure by fine screw movements of the
spar S.

The electro-optic cell is not given in the diagram.   It is the same
piece as that shown in the diagram of the first arrangement, and is
placed here exactly as there, so that the two laterally-separated
component pencils pass normally through it, BF through the electric
field, and CG behind the second conductor.

The only other optical piece employed in the experiments is a
Jamin's Glass Compensator,† which is placed immediately in front of
the spar S; it enables the observer to specify small differences of re-
tardation of the pencils BF and CG.

The results obtained formerly (with nicol N as eye-piece) were
fully verified with the new apparatus.   The method finally adopted
as the best was so similar to the former, and the effects also, that
any long description of the experiments would be superfluous.   But
to give a fair view of the results I will describe one day's work.

---

* "On the Bi-refringent Action of Strained Glass," 'Phil. Mag.' for October,
1888.

† Preston's 'Theory of Light,' p. 159.

Final Experiments with CS$_2$.—The first internal conductor connected permanently with prime conductor without Leyden jar, the liquid quite clean, and the conditions of electric work perfect all day. The observations were taken in five successive sets.

First Set.—Plane of polarisation of the pencil BF (through the electric field) vertical, or perpendicular to line of force: Rise of fringes indicates relative retardation of that pencil. When the fringes were obtained in good form and position, the machine was started, and kept working at a constant rate throughout the experiment. As formerly, the first effect was a large disturbance, the fringes being displaced and deformed, and disappearing altogether at the second or third turn of the plate; but in a little time (thirty or forty turns) they reappeared in good form and approximately constant position. For distinctness of effect the central fringe was brought back to the line of reference (generally downwards) by a small screw movement of the spar S; and then, at every spark from prime conductor to earth, there was a quick downward jump of the fringes, the effect being as distinct as possible from the irregular and slow and generally small movements that went on before and after the spark. As the experiment proceeded the liquid was more thoroughly mixed, the disturbance decreased, and the effect came out much more purely. Sparks were taken repeatedly at every 3rd, 5th, 10th, 15th turn of the plate, and the jump was there in every instance, and beautifully distinct. The extent of the jump varied from about one-third of the fringe-width at every 5th turn of the plate to about three-fourths at every 10th turn. I should add that the disturbance movements, though they were greatly reduced at last, were still such as to prevent any good static observation of the fringes.

It is proved clearly by this set of observations that when the plane of polarisation is perpendicular to the line of force the light is absolutely retarded by electric strain. The spars R and S were now turned round LE through 180°, and the pieces were moved across the optic bench into good position.

Second Set.—Plane of polarisation of the pencil BF (through the electric field) horizontal: Rise of the fringes indicates a relative retardation of that pencil. The method was the same as in the first set, sparks being taken from prime conductor to earth at regular intervals, long and short. When the initial disturbance was over, movements of the fringes were still seen, sometimes in one direction and sometimes in the other, but not exclusively or specially at the instant of discharge. These disturbance movements were slow and generally small; and as the experiment proceeded they became very faint, and were occasionally not seen at all for a little time. As to the effect specially looked for, I need only say that in several scores

of observations, taken at different potentials, high and low, there was not a trace observed of a regular jump of the fringes at the instant of discharge. It appears, therefore, that when the plane of polarisation is parallel to the line of force, the light is neither retarded or accelerated by electric strain. The spars R and S were now turned back through 180°.

Third Set.—The same again as the first. Many observations were taken, and the former effects were obtained regularly; but they were now more striking, because of the strong contrast with the negative results of the set of observations immediately preceding. The action appeared also to be stronger than before, probably because of improved insulation. The extent of the jump, taken at every 5th turn of the plate, was now half the fringe-width; and at every 10th or 15th turn it was clearly four-fifths. I find in my notes that this large jump of the fringes impressed me here, again and again, as a thing peculiarly beautiful.

Fourth Set.—The same again as the second. The only question in this case was, whether it might still be possible, by the most careful work and under the best conditions attainable, to detect a very small jump of the fringes at the instant of discharge. Many observations were taken at high potential, some at the highest, but without a trace of effect of that kind.

Fifth Set.—The same again as the first. The results of the first and third sets were recovered regularly. Sparks were then taken, sometimes at every turn of the plate, sometimes oftener. At every spark there was a very small downward jump of the fringes, so small sometimes as to be barely caught, but quite regular and beautifully distinct.

Remarks.—The jump of the fringes was chosen as the principal object of observation, because it was never quite concealed, nor even much obscured, by the mechanical disturbance of the liquid; but I should add that the contrary motion—the gradual ascent of the fringes during the process of charging—was generally evident enough in the experiments, though not often undisturbed or quite regular in its course.

The best observations were got when the fringes happened to continue at rest through a sensible interval of time, including the instant of discharge. The contrast between the two cases was then very remarkable, especially at high potential; in the one case, the beautifully clear jump so often mentioned; in the other case, no trace of a jump in either direction, generally not even a perceptible shiver of the fringes at the instant of strongest discharge. Instances of this kind occurred not very rarely in the experiments; and there could be no contrast more striking than that between the phenomena in the two cases.

From what I know of the apparatus and its performance I am sure that no regular and abrupt retardation or acceleration amounting to as much as the *hundredth* part of an average wave-length could have escaped observation in the experiments. It will be remembered also that the jump of the fringes at high potential extended to *four-fifths* of the fringe width. With reference, therefore, to the dielectric CS_2, and the two principal vibrations parallel and perpendicular to the line of force, it appears that the regular effect of the electric strain upon one of the vibrations is a positive retardation, while upon the other vibration there is very probably no effect whatever, and certainly no effect as large as the *eightieth* part of the former.

Second Positive Dielectric: A paraffin oil, specific gravity 0·845. This liquid was far inferior to CS_2 electrically, and also as an optical medium. The method of experiment finally adopted as the best was a little different from that with CL_4. The prime conductor had its capacity enlarged by connexion with a Leyden jar; the machine was kept working at a constant rate, and the prime conductor was partially discharged, at short and regular intervals, by sparks upon the knob of the first internal conductor, which was of course discharged in each interval. The phenomenon looked for was a quick motion of the fringes at the instant of the spark; that is, at the instant of electric charging of the liquid.

(1.) Plane of polarisation of the pencil BF (through the electric field) vertical: Rise of fringes indicates relative retardation of this pencil. At the instant of the spark there was a quick upward jump of the fringes through something like one-fifth of the fringe width, generally followed by a set of large and comparatively slow disturbance-movements. In most cases also, immediately after the spark, the observer was able to detect the contrary jump quite clearly by laying his finger on the knob of the first conductor. Through a long set of observations, taken at different potentials, the upward jump of the fringes at the instant of charging was obtained with perfect regularity; and—amplitude excepted—the effect was not inferior to that in CS_2.

(2.) Plane of polarisation of the pencil BF horizontal: Rise of fringes indicates relative retardation of BF. Many observations were taken at different potentials, high and low. There were sluggish and irregular disturbance movements, great and small, but no trace of a regular jump of the fringes in one direction or the other at the instant of the spark. There could be no doubt as to the true meaning of these results. In this positive dielectric, as in CS_2, the vibration along the line of force is retarded by electric strain, and the perpendicular vibration is unaffected.

First Negative Dielectric: Oil of Colza.—This liquid also was far inferior to CS_2, especially as an optical medium. The method of

experiment followed with paraffin was retained here as the best; the first internal conductor was charged by spark from the prime conductor at regular intervals, and was put to earth for a moment in each interval.

(1.) Plane of polarisation of the pencil BF vertical: Rise of fringes indicates relative retardation of BF. The fringes were generally curved and very imperfect at the beginning of an experiment, but a few successive charges brought them, after some disturbance, into permanently good form, and then there was a quick downward jump, seen always at the instant of the spark. And, as in the contrary case of paraffin, this jump was a thing as distinct as possible from the sluggish and irregular disturbance-movements by which it was generally followed. When the spark was taken at every 10th turn of the plate, the potential was about as high as the liquid could bear, and the extent of the jump was fully one-fifth of the fringe-width. In the course of a long set of observations this downward jump of the fringes at the instant of charging was seen with perfect regularity, and always distinctly. In this case, therefore, the regular optical effect of electric strain was an acceleration.

(2.) Plane of polarisation of the pencil BF horizontal: Rise of fringes indicates relative retardation of BF. When the fringes were imperfect at. starting, the effects of a few successive charges were the same as in the first case, irregular displacements and changes of inclination, the fringes generally rising and falling in their lower and higher parts till they came into permanently good form. Afterwards there were smaller disturbances always present in this case as in the former; but neither there nor here were they such as to interfere ultimately with exact observation. The experiment was carried on for some time till the liquid was well mixed and the fringes good. Many observations were then. taken, some of them at highest potential, but there was no trace of a jump ever seen at the instant of the spark. In this liquid, therefore, as in carbon disulphide and paraffin, the only one of the two principal vibrations which is affected by electric strain is that along the line of force; but, as the present dielectric is of the negative class, the retardation produced is negative.

Second Negative Dielectric: Seal Oil.—From want of homogeneity this liquid was very defective optically, the image of the slit L being much deformed and sometimes broken by streaks. The defect was remedied in a good degree by strong charges given to the liquid on both sides of the second conductor. The method of experiment was the same as with oil of colza.

(1.) Plane of polarisation of the pencil BF vertical: Rise of fringes indicates relative retardation of BF. At first, the electricity produced very large displacements and deformations of the fringes, in

the midst of which there was no regular effect to be seen; but as the experiment went on, and the medium improved, the expected effect came out distinctly: a quick downward jump of the fringes at or immediately after the instant of the spark. Under good optical conditions, and at potentials high and low, the effect was perfectly regular, and was distinct and pure as that in oil of colza, though apparently not quite so large.

(2.) Plane of polarisation of the pencil BF horizontal: Rise of fringes indicates relative retardation of BF. The disturbance of the fringes was greatly reduced as the experiment went on, till at last there was nothing left but a set of slow movements, very irregular and very small, sometimes invisible. In the midst of these, as in their absence, and in a long set of observations, taken at different potentials, from low to highest, there was no trace ever seen of a jump of the fringes at the instant of the spark. It appears, therefore, that in this negative dielectric, as in oil of colza, the total optical effect of electric strain is an acceleration of the vibration which is directed along the line of force.

The conclusion to be drawn from the preceding experiments has been stated already by anticipation; but I repeat it finally in other terms as follows:—

If light pass through an electrostatically-strained medium at right angles to the lines of force, and be represented by two component lights whose planes of polarisation are respectively parallel to the lines of force and perpendicular, then the proper and immediate optical effect of the electric strain is a change of velocity of the latter component.[*]

The use of the words *proper and immediate* in this statement may be thought objectionable; but some such words are required for the purpose here chiefly intended, which is to exclude those undoubtedly remote effects of electric action that appeared as disturbances in all the experiments.

IV. "On the Liquation of Silver-Copper Alloys." By EDWARD MATTHEY, F.C.S., Assoc. Roy. Sch. Mines. Communicated by Sir G. G. STOKES, F.R.S. Received February 16, 1894.

It is a well-known fact that during the solidification of certain alloys groups of the constituent metals fall out of solution, giving rise to the phenomenon called "liquation." The molecular arrangement which results from this behaviour of alloys has been investigated by many experimenters, notably by Devol, Roberts-Austen, and Guthrie. The author has also studied the behaviour of a large

---

[*] The change of velocity in the case of any positive dielectric is of course a decrease.

series of the alloys of the precious metals and metals of the platinum group, and the results have been published in the 'Philosophical Transactions' for 1892, and in other papers to which reference may be made.* It is, however, in the case of alloys of silver and copper that liquation is most marked, and gives rise to results of much interest and industrial importance. It is, for instance, often a matter of great importance to obtain a plate of standard silver (925 parts of silver in 1000) of *uniform standard*. The great difficulty of effecting this has been shown by Roberts-Austen†, and, as the results of an elaborate series of experiments, he was led to the conclusion that slow and uniform cooling of the mass was most effective in obtaining uniformity of standard. He informs me of a fact of which I was not aware until the present experiments were concluded, viz., that he also tried the effect of the rapid cooling of a thin casting in a large mould which was no less than 45·7 cm. long. He found, however, that castings made in this mould were comparative failures as regards uniformity of standard, and that, as in the case of other published results given by castings in thicker moulds, it was not possible, either by rapid or by slow cooling, to obtain masses of alloys which did not give points of local richness.

During the last few years I have returned to the investigation of the silver-copper alloys, and as the results of a series of some hundreds of experiments, only the final ones of which must be referred to here, I find that it is preferable to cast the alloy very thin, and to promote the uniformity of cooling.

A bar of this alloy was cast into a "skillet" mould to produce a casting 30 cm. in length, 13 cm. in width, and 6 mm. in thickness, weighing 5 kilos. Punchings were taken through its thickness at the points marked, and the assays which were made of these punchings showed the composition at the respective points to be as follows :—

* 'Phil. Trans.,' 1892, A, pp. 629—652, and 'Roy. Soc. Proc.,' vol. 47, 1890, pp. 180—186.

† 'Roy. Soc. Proc.,' vol. 23, 1875, p. 481, and 'Chem. Soc. Journ.,' vol. 27, 1874, p. 197.

RESULT A.

924·4   924·4

925·1   925·1

925·1

925·1   925·1

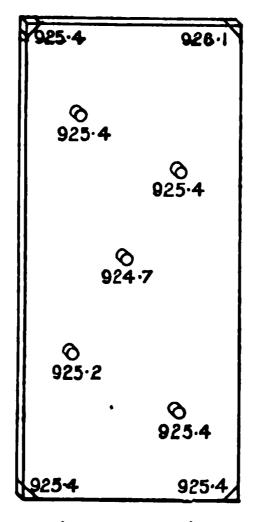924·4   924·4

Average, 924·78.
Maximum Variation, 0·7 per mille.

Showing a very slight tendency to liquation of silver to the centre here.

And another bar cast at a higher temperature in the same mould showed the qualities indicated at the points given.
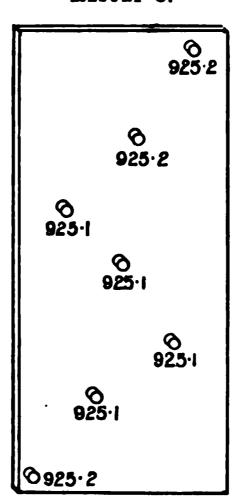
RESULT B.

925·4   926·1

925·4

925·4

924·7

925·2

925·4

925·4   925·4

Average, 925·37.

No liquation of silver to the centre.

I ultimately reduced the thickness of the mould to 4 mm., and cast a bar into this, with the results shown in diagrams C and C'.

RESULT C.

Average, 925·14.
Maximum variation, 0·1 per mille.

RESULT C'.
(C rolled laterally to one mm. thickness.)

Average, 925·02.

These results will, I think, be considered sufficiently remarkable by metallurgists who have been accustomed to deal with castings of standard silver. It must not be supposed, however, that liquation has been entirely prevented ; *it has, however, practically disappeared.*

The excellent results now submitted to the Society have been obtained by limiting the possibilities of re-arrangement as much as may be, and by ensuring that the conditions of cooling shall be as uniform as possible. The need of obtaining uniform alloys is met with in other branches of industry than those which involve the use of silver-copper alloys, so that the conclusions to which the present experiments point are somewhat far-reaching.

V. "A Contribution to the Study of Descending Degenerations in the Brain and Spinal Cord, and of the Seat of Origin and Paths of Conduction of the Fits in Absinthe Epilepsy." By RUBERT BOYCE, M.B., Assistant Professor of Pathology, University College, London. Communicated by Professor V. HORSLEY, F.R.S. Received February 8, 1894.

(From the Pathological Laboratory of University College, London.)

(Abstract.)

For the purposes of this research, the following are the experiments which have been performed in the cat :—

I. *Lesions after which Animal was Kept Alive.*

1. Removal of one complete cerebral hemisphere in 40 cats.
2. Removal of motor area only in 4 cats.
3. Division of the crus cerebri in 2 cats.
4. Removal of a lobe of the cerebellum in 10 cats.
5. Hemisection of the spinal cord in 4 cats.
6. Complete section of the spinal cord in 2 cats.

II. *Lesions after which Animals were not Kept Alive for any Length of Time.*

1. The preceding operations.
2. Removal of both cerebral hemispheres.
3. Removal of the cerebellum.
4. Removal of one cerebral hemisphere and opposite lobe of cerebellum and *vice versâ.*
5. Removal of one hemisphere and division of opposite half of the spinal cord.

Where the animals have been kept alive, the symptoms during life and the anatomical changes found after death have been investigated, and in all cases the results of absinthe stimulation have been recorded by the graphic method.

In order to enable a clearer comparison to be made between the various results obtained by the experimental and anatomical methods, the paper is divided into—

    I. The anatomical changes.
   II. Behaviour of the animal during life.
  III. Results of absinthe stimulation.
  IV. Conclusions.

Part I.—*Anatomical Changes.*

The investigations of the degenerations have been made in every instance by the Marchi method upon animals which have been kept alive from a few days to three months.

Removal of one Cerebral Hemisphere (Left), or complete Section of the Left Crus Cerebri flush with the Tentorium.

The results of these lesions as regards the descending degenerations are identical.

They show that in the higher bulbo-spinal segments, from the 3rd nerve downwards, there exist long descending internuncial fibres, which are grouped anteriorly and laterally as in the spinal cord; in other words, that the anterior, antero-lateral, and lateral columns of the cord can be traced from the level of the superior corpora quadrigemina.

Anterior Columnar Fibres.—These fibres begin to group at the level of the uppermost part of the 3rd nerve against the anterior and inner aspect of the grey matter of the aqueduct of Sylvius; they constitute the commencement of the posterior-longitudinal bundle. The degenerate fibres are absolutely limited to the side of the lesion; they occupy, for the most part, the inner portion of the posterior-longitudinal bundle, and they can be traced to the end of the cervical spinal cord. The higher the lesion the fewer are the number of degenerate fibres in the post.-longitudinal bundles; if the lesion extends much below the 3rd nerve, the degeneration of the post.-longitudinal bundle is very complete. New fibres are continually being added to the post.-longitudinal bundle in its passage through the bulbar segments, the degenerate fibres in consequence moving more anteriorly. In the spinal cord the degenerate fibres are scattered through the middle and post.-thirds of the anterior column on its inner aspect and closely simulate a direct pyramidal tract.

Antero-lateral Columnar Fibres.—*Meynert's fibres* (fountain decussation) pass from the side of the lesion across the raphe immediately ventral to the post.-longitudinal bundles, and turn vertically down, lying in the raphe in front of the post.-longitudinal bundles. The fibres can be traced into the antero-lateral column of the cord as far as the lower cervical region. In their descent they move slightly forwards, but they are always more anterior than the fibres of the post.-longitudinal bundles. The degeneration method shows that Meynert's fibres arise in a focus close to the point of commencement of the descending root of the 5th, on a level *with the roots* of the 3rd nerves. The vast majority of the fibres decussate completely; the decussation is a very horizontal one.

Lateral Columnar Fibres.—In the highest segments these are derived from fibres, which decussate in front of the preceding group, and originate from a slightly higher level in the tegmentum; they probably correspond to Forel's decussating fountain fibres. In the mesencephalon they occupy a position in front of and slightly external to the antero-lateral columnar fibres; lower down they are more laterally situated, and in the pons and medulla form a well defined group, immediately in front of the ascending root of the 5th and the substantia gelatinosa, and dorsal to the nucleus lateralis; they are traversed by the root of the 7th, and are bounded externally by trapezoid, and ascending cerebellar fibres. They are internal to the lemniscus and quite distinct from it; they can be traced to the upper lumbar spinal cord. In the spinal cord they occupy a position immediately in front and to the outer side of the pyramidal tract; they are readily distinguished from the latter by their large size.

Degeneration of Descending Root of 5th.—The Marchi method shows that this root is invariably degenerate upon the side of the lesion. It arises in the lateral aspect of the Sylvian grey matter at about the level of the upper oculo-motor nucleus, descends to meet the ascending root, and passes out without interruption.

Pyramidal System.—The degeneration is confined exclusively to the pyramid on the side of the lesion, and the degeneration appears complete.

There is a slight *bifurcation* at the decussation, a small group of fibres passing back to the lateral tract on the same side. There is thus a *direct lateral pyramidal tract*, but there is no *anterior* direct pyramidal tract.

The decussation of the pyramid is not confined to the cervical region; degenerate fibres leave the pyramidal system from the internal capsule, the crusta, and from the pyramid in the medulla. A large group passes through the thalamus and beneath the corpora quadrigemina, many of the fibres crossing over in the roof of the aqueduct. A considerable number of degenerate fibres pass back to

the quadrigeminal region from the outer and dorsal part of the crusta.

In the *posterior commissure, pineal commissure,* and *corpus callosum* there are numerous degenerate fibres.

When the motor area or anterior third of the brain is removed, the degeneration is confined to the pyramidal system, the contrast with the results of hemisection of the mesencephalon being, therefore, very striking.

Comparing hemisection of the mesencephalon with hemisection of the cord, the difference, as regards the internuncial fibres, is the greater amount of decussation in the mesencephalon than in the cord. The internuncial fibres are conspicuous by their large size.

Comparison with ascending degenerations at the various levels shows that the descending tracts described above are distinct from the ascending.

Lesion of the Cerebellum.—When one lobe of the cerebellum is removed there is degeneration of the superior cerebellar peduncle. I have found no evidence of the descending columnar degeneration described by Marchi.

PART II.—*Symptoms of Animals during Life.*

Comparing the relationship between the extent of the degenerations and the symptoms, it is found that—

Removal of the motor area entails degeneration of the pyramid alone, and a temporary paresis; the animal appearing, after a short time, quite like the normal.

Removal of a cerebral hemisphere or hemisection in the quadrigeminal region gives rise to degeneration of the pyramidal and internuncial systems and fibres. The symptoms are more pronounced; sensation is much altered; there is great difficulty of feeding.

Hemisection of the cervical spinal cord produces extensive degeneration of the anterior and lateral columns of the cord. There is at first hemiplegia, the vasomotor disturbance is much greater, and the sensory and motor paresis lasts longer.

Removal of a lobe of the cerebellum does not appear to be accompanied by descending columnar degeneration; the symptoms may be very slight, or there may be incoordination and sensory and motor weakness upon the side of the lesion. The manifestation of the motor weakness differs from that seen in the cats, in which the pyramid is degenerate. There is no wrist drop in the cerebellar cat. The weakness in the case of the pyramidal cats is uncomplicated; on the contrary, that in the cerebellar cat is intimately bound up with complex phenomena of incoordination.

The evidence would tend to show that the weakness in the two cases is due to different causes.

PART III.—*Results of Absinthe Stimulation.*

The absinthe has been injected either immediately after the operation or after complete recovery. There are, therefore, two categories of experiments, viz., "immediate" and "remote"; but, as a rule, the difference between the average results in both cases is slight. The fit was registered by spring myographs attached to the extensor tendons of the fore paws.

1. *Removal of one Cerebral Hemisphere, or Hemisection of the Mesencephalon, and Immediate or Remote Absinthe Stimulation.*

Result.—There are bilateral fits. On the paretic side the initial fit may be much smaller than on the left side; in the subsequent fits, tonus is more marked than clonus; the final clonic contractions are less numerous.

2. *Removal of Left Motor Area; Immediate and Remote Stimulation.*

Result.—The fits upon the right and left sides more closely resemble one another; there is considerable clonus upon the "paretic" side as well as upon the normal.

3. *Removal of both Hemispheres.*

Result.—Immediate removal of the hemispheres arrests the fits; a slight respiratory response can, however, be elicited. Where one hemisphere has been first removed, and after recovery the remaining hemisphere and absinthe has been given, contractions have been obtained, occurring at regular intervals and equal upon both sides; in one case the contraction was most marked upon the side corresponding to the hemisphere first removed. Removal of both hemispheres and stimulation upon the second day was followed by two strong fits, made up of a series of contractions following one another fairly rapidly, but not so rapidly as in the clonus when a hemisphere is present.

Where both motor areas have been removed in succession, regular tonic and clonic bilateral responses have been obtained; the rhythm of the clonus is much slower than when the cortex is intact.

4. *Removal of Cerebellum and Immediate Absinthe Stimulation. Removal of one Lobe of the Cerebellum. Removal of Left Hemisphere and Left Lobe of the Cerebellum. Removal of Left Hemisphere and Right Lobe of the Cerebellum and v. v. Immediate and Remote Absinthe Stimulation.*

Result.—Removal of the whole cerebellum does not stop the fits, nor impart to them any special character. Removal of one lobe of the cerebellum appears to have very little effect upon the fits. Where, in addition the opposite cerebral hemisphere is removed, the fits appear similar to those seen when the hemisphere alone is removed.

5. *Removal of Left Hemisphere and Subsequent Section of the Right and Left Halves of the Cervical Spinal Cord.*

Result.—Conduction abolished on the side of section.

6. *Hemisection of the Upper Cervical Spinal Cord and Absinthe Stimulation.*

Result.—In cats which have partially recovered from the effects of the hemisection, absinthe produces a response upon the side which was divided.

7. *Complete Section in the Dorsal Region.*

Result.—In two cases of complete recovery (complete paralysis of the hind quarters remaining), absinthe did not elicit a response from the distal segment of the cord; the experiments, however, require repeating.

PART IV.—*Conclusions.*

The formation of the descending system of the anterior, antero-lateral, and lateral columns can be seen in the mesencephalon.

There is a marked decussation of the lateral and antero-lateral column fibres in the mesencephalon. The anterior column fibres (post.-longitudinal bundle) appear to be direct fibres. Decussation is, however, not limited to this region; it occurs in the spinal cord, and probably throughout the bulbo-spinal system.

Decussation of the pyramidal system is not limited to the cervical region; it occurs in the higher segments. As in the preceding system so in this, there is a direct path—the direct lateral pyramidal tract, and there is evidence of direct fibres in the higher segments.

There is bilateral distribution of both systems of fibres, but there is no evidence whatever of recrossed fibres.

No fibres get into the opposite pyramid by way of the corpus callosum.

Stimulation with absinthe shows that the bulbo-spinal centres (including the cerebellum) alone, can produce a series of clonic fits, differing from the cortical in the much slower rhythm of the contractions.   But from the complete section of the cord experiments it seems improbable that the cord alone can be excited by absinthe.

Immediate hemisection of the cord prevents the absinthe fit on that side; but after recovery a modified fit results upon the side of the lesion, in spite of the fact that the direct lateral and crossed pyramidal tracts are completely degenerate, as well as the internuncial fibres in the anterior and lateral columns.

When one hemisphere is removed or a complete hemisection made in the quadrigeminal region, there are bilateral fits, in spite of the fact that one pyramidal system is completely degenerate.   The fits are modified upon the side opposite to the lesion, the clonus being less marked, and the first fit being absent or very small.

If, in the last two cases, a hemisection is made upon the side of the degenerate pyramid, it instantly arrests the fits upon that side, the section interrupting the sound direct pyramidal tract.

I therefore conclude that the maximal effect of absinthe is produced when the motor area is present, and that the impulses generated there are distributed by the pyramidal system in the way described, the maximal effect crossing to the opposite side, the question of unilaterality or bilaterality being one of degree as shown by the differences between the initial and subsequent fits, and as borne out by the relative sizes of the crossed and uncrossed tracts.

The epilepsy due to absinthe indicates that there are probably very many epileptiform attacks in man which are toxic.

VI. " A Research into the Elasticity of the Living Brain, and the Conditions governing the Recovery of the Brain after Compression for Short Periods."   By A. G. LEVY, M.B. (London).   Communicated by Professor HORSLEY, F.R.S. Received February 21, 1894.

(From the Laboratory of the Pathological Department of University College, London.)

(Abstract.)

In view of the great frequency of compression of the brain as a pathological condition, it seems very advisable to attempt to obtain

some knowledge of the elementary factors conditioning the physical changes in the brain substance due to mechanical pressure.

Grashey* has already definitely proved that the coefficient of compressibility of the dead brain is slightly less than that of water, which is equivalent to saying that under any ordinary pathological conditions the brain tissue is incompressible. At the suggestion of Professor V. Horsley, who devised an apparatus for the purpose, and to whom I am indebted for advice and suggestions, an attempt was made to determine the elasticity of the living brain, *i.e.*, of the brain mass with its full complement of circulating blood and lymph, and further to test the truth of the generally accepted view that the elasticity of the brain is proportional to the blood pressure.

The brain was experimented upon *in situ*, the influence of the cerebro-spinal fluid being excluded by the mere fact of the skull being opened and the membranes partially reflected, thus releasing the fluid from all tension. Thus we arrive at the properties of the brain mass itself as it rests upon its osseous enclosure.

There were, in the first place, considered the results of experiments performed upon freshly-exposed brains, the blood pressure being at its normal height, in order to arrive at some conclusion as to the normal elasticity of the brain. The downward movement of a plunger was measured after a given interval of time, and the extent of this is termed the "excursion." The recovery of the brain surface, to the extent of which the term "recoil" is applied, was measured until it failed to perceptibly develop further. The general character of the excursion is that of a rapid plunge downwards taking place within the space of one or two seconds, followed by a much more gradual compression. Its extent varies within a considerable range in different animals; thus a weight of 50 grams applied for one minute produces an excursion which varies in different dogs from 4·5 to 7·3 mm. It also varies notably with the weight employed. There is no obvious relation between the depth of excursion and the blood pressure.

For convenience of expression and of comparison the ratio of the excursion to the recoil is in the full paper expressed in the form of a fraction, and this ratio is termed the "proportionate recoil;" the smaller this fraction the feebler the elastic reaction it denotes, and *vice-versâ.* A comparison of the ratios derived from experiments performed under like conditions upon different animals brings out the striking approximation which they bear to one another, whatever the length of the excursion and whatever the existing blood pressure may be. And such deviations from the average as the ratios present cannot be found to have any relation to variations in either excursion or blood

* Grashey, " Ueber Hirndruck und Hirncompression." ' Allg. Ztschr. f. Psychiat.,' Berlin, 1887, vol. 43.

pressure. A compression by a 50-gram weight for a period of from 30 seconds to one minute yields an average proportionate recoil of $\frac{1}{2}$. A further comparison definitely shows that the longer the period of compression the less is the recoil; thus with a compression of only two seconds the reaction is sometimes almost perfect, whereas a compression lasting six minutes yields a ratio of 1/2·74. Heavier weights similarly damage the brain in a fashion prejudicial to its recovery.

A series of experiments were performed with a view to comparing the " elasticity " of the brain at the normal blood pressure with the " elasticity " of the same brain at an artificially lowered blood pressure. The first method employed was that of producing a large fall of blood pressure by bleeding. The results tended to confirm the impression that there exists no constant relation between brain elasticity and blood pressure. This series is somewhat vitiated by the partial collapse of the cerebrum which ensues during the process of bleeding, and a second series was instituted, in which the blood pressure was lowered through the agency of amyl nitrite; the brain at the moment of administration becoming flushed with blood, it has no tendency to collapse. Under the influence of this drug the cerebral vascular conditions are such that the " elasticity " is actually increased, thus conclusively demonstrating the non-dependence of the latter upon the central arterial pressure.

A further series of experiments were performed in view of the influence which venous pressure is believed to exert upon the cerebral circulation. This object was carried out by exposing the accessible cranial veins and clamping them in succession, and by measuring the variation in the intra-cranial pressure induced by this means. The results tended to show that the increase of intra-cranial pressure must be considerable to influence the " elasticity " in even a small degree.

Experiments performed upon brains which had undergone prolonged or severe compression showed that a considerable increase of arterial blood pressure is quite unable to restore the volume of the brain thus damaged, whereas an increase of venous pressure, obtained by asphyxiation, rapidly, and usually completely, brings this about.

VII. "On the Effects produced on the Circulation and Respiration by Gunshot Injuries of the Cerebral Hemispheres." By S. P. KRAMER, M.D., and VICTOR HORSLEY, M.B., F.R.C.S., F.R.S., Professor of Pathology in University College, London.   Received February 21, 1894.

(From the Laboratory of the Pathological Department, University College, London.)

(Abstract.)

In consequence of the fact that the effects produced on the circulation and respiration by a bullet passing through the cerebral hemispheres are but little understood, the authors instituted a series of pathological experiments on etherised dogs, and of physical experiments on various substances.

The results obtained establish, beyond question, that the primary cause of death under these circumstances is not, as is usually supposed, due to failure of the heart, but to arrest of the respiratory movements. Further, the authors have found, in confirmation of this, that death can be prevented by the employment of artificial respiration, except under certain circumstances detailed in the paper.

After describing the changes in the circulation produced, and which consist of (*a*) slight initial fall of blood pressure, (*b*) considerable later rise of blood pressure, (*c*) preservation of the rhythm of the heart, the authors discuss the physical effects of the projectile on the encephalic contents, and they show, as was originally contended by Professor Kocher, that the action of the bullet is essentially a hydrodynamic one, and that it is the lateral pressures which cause mechanical lesion of the respiratory centre.

In this respect the results obtained further support the original observations of Spencer and Horsley, recently confirmed by Hill, viz., that the respiratory centre is the first to be seriously affected by changes in the intra-cranial tension.

Finally the authors point out that, supervening on the primary arrest of respiration, there ensues a gradual rise in the intra-cranial tension due to the hæmorrhage within the skull cavity, and that the phenomena which then follow are the same as those described in the above-mentioned paper.

VIII. "On the Influence of Carbonic Acid and Oxygen upon the Coagulability of the Blood *in Vivo*." By A. E. WRIGHT, M.D. (Dubl.), Professor of Pathology, Army Medical School, Netley.   Communicated by AUGUSTUS D. WALLER, M.D., F.R.S.   Received February 8, 1894.

I have, in the course of previous researches on blood coagulation,* had occasion to suggest that the phenomena with which I was dealing might be explained in a very simple manner by assuming that carbonic acid gas exercised a favourable influence on the occurrence of blood coagulation.   The present research consists of an examination of the hypothesis in question.

The method of experimentation employed consisted in determining the alterations of blood coagulability which occurred in animals when alterations were effected in the respiratory gases with which they were supplied.

Details of the Method of Experimentation employed.

The animals experimented upon were dogs and rabbits.   The animals were in all cases tracheotomised under the influence of ether (rabbits) or of a mixture of ether and chloroform (dogs).   In the case of the dogs, the animals were kept under the influence of the chloroform and ether during the whole course of the experiment.   In the case of the rabbits, the repeated inhalations of carbonic acid and other gaseous mixtures served to keep up the anæsthesia.   The tracheotomy tubes were connected up with a T-tube; one limb of the T-tube was fitted with a Speck's intestinal valve (made of rabbit-gut), and allowed of free expiration into the outer air.   The other limb of the T-tube was connected up at pleasure with reservoirs (4,000 c.c. capacity) of pure gases or gaseous mixtures standing over water.   The water was carefully kept at the same level inside and outside of the reservoirs during the whole course of an experiment.   A convenient check upon this was afforded by the regular opening and closing of the intestinal valve.

The blood for the coagulability estimations was obtained from the ear.   In the case of the rabbits, the blood was invariably drawn off from the central artery of the ear.   Only rabbits with full ear arteries were employed in the experiments.

The blood coagulability determinations were made by the method of capillary coagulation tubes recently† described by me.   The method

* 'Journ. of Physiol.,' vol. 12, No. 2; 'Roy. Irish Acad. Proc.,' 3rd Series, vol. 2, No. 2; 'Roy. Soc. Proc.,' February, 1893.

† 'Brit. Med. Journ.,' July 29th, 1893, and February 3rd, 1894.

differs from the method previously described by Vierordt* in the following particulars:—1. A series of capillary tubes, of equal calibre, is employed instead of the single capillary tube employed by Vierordt. 2. Coagulation time is determined by blowing down the capillary tubes, one after another, at regularly increasing intervals until a tube is found to have become blocked by clot. In Vierordt's method the occurrence and duration of coagulation is judged of by passing a chemically cleansed white horse-hair down the capillary tube, and observing the deposition of coagulum upon its surface.

In all cases I employed a column of blood of 5 cm. in length, and received it into tubes† which had a diameter of approximately 0·25 mm.

The following precautions were observed in order to ensure accuracy of results:—1. The coagulation tubes were washed out before use successively with distilled water, absolute alcohol, and ether. 2. They were then warmed in an incubator to a temperature of 37° C. 3. A fresh drop of blood was employed for filling each tube. 4. The column of blood was aspirated some little distance up the tubes to prevent desiccation occurring at the orifice. 5. In testing for coagulation the blood was blown out on to a piece of white filter paper in order to ensure the detection of the first traces of clot.

The gases which were experimented with were the following:—Atmospheric air, oxygen, hydrogen, carbonic acid, and a mixture of (approximately) 20 per cent. of oxygen with 80 per cent. of carbonic acid. I also examined the effect of clamping the trachea.

Effect of an Increase of Carbonic Acid.

In order to elicit the effect of an increase of carbonic acid upon coagulability, I caused the animals to inspire out of a reservoir containing a mixture of 1 part (approximately) of oxygen with 4 parts of carbonic acid. This mixture of gases presents the obvious advantage of supplying carbonic acid in association with the normal quantum of oxygen. Determinations of blood coagulability were made when the animals were breathing this mixture of gases, and the results were compared with the " coagulation times " which were elicited immediately before when the animals were breathing atmospheric air. Thirty experiments were made. Out of these twenty-seven showed a marked increase‡ of coagulability while the animal was breathing the mixture of carbonic acid and oxygen. In two experiments coagulation time was unaltered, and only in one experiment was a slight diminution of coagulability observed.

* ' Archiv für Heilkunde,' 1878.

† These tubes were supplied by Mr. A. E. Dean, Jun., 73, Hatton Garden E.C.

‡ This increase of coagulability is well shown in the first ten of the protocols appended to this paper.

In the three experiments last mentioned the coagulability of the blood was already at a maximum when the animal was breathing atmospheric air.

It is to be noted that the blood which was drawn off while the animal was breathing the carbonic acid and oxygen was arterial in colour in all the experiments which have been summarised above. The increase of coagulability must therefore be ascribed to the increase of carbonic acid in the blood, and not to any defect of oxygenation.

It has thus been demonstrated that the increase of carbonic acid in the blood does exert a favourable influence on coagulation.* Carbonic acid is therefore in all probability what I assumed† it to be, *i.e.*, a *vera causa* in the determination of intravascular coagulation to particular vascular areas.

Effect of a Diminution of Carbonic Acid.

This question was studied by examining the condition of coagulability in animals when an atmosphere rich in carbonic acid was replaced by (*a*) ordinary air, or (*b*) by oxygen.

a. Results of experiments in which an atmosphere of carbonic acid was replaced by ordinary air.—The result‡ of such a replacement of carbonic acid and oxygen by atmospheric air is a decrease of coagulability to the original norm.

b. Results of experiments in which an atmosphere of carbonic acid and oxygen is replaced by an atmosphere of unmixed oxygen.—The substitution of unmixed oxygen for the mixture of carbonic acid and oxygen is invariably followed by a decrease of coagulability. The diminution may be due to a specific effect of an atmosphere of unmixed oxygen. On the other hand it may with much greater probability be referred to the diminution of carbonic acid in the blood, for the rate of respiration is always extraordinarily accelerated (to 160 respirations per minute and upwards) by the inspiration of oxygen. This view is also suggested by the analogy of the experiments in which air is substituted for the carbonic acid mixture. It is further supported by the fact that the diminution of coagulability is apparently proportionate to the amount of carbonic acid which is present in the blood. The diminution is, for instance, well marked

---

* I have found this statement to hold true also in the case of human blood. The inhalation of an atmosphere which is rich in CO_2 causes an increased coagulability in my own blood. I have obtained a similar increase of coagulability (associated with an arrest of hæmorrhage) in a case of severe bleeding in hæmophilia. I have also obtained an increased coagulability by inhalation of CO_2 in the case of three members of another hæmophiliac family.—21/2/94.

† 'Journ. of Physiol.,' vol. 12; 'Roy. Irish Acad. Proc.,' 3rd Series, vol. 2, No. 2.

‡ This result is well shown on the protocols of rabbit 161 and dog 2.

when the blood is rich in carbonic acid (*e.g.*, in protocols of rabbits 165, 163 and 135), while there is practically no diminution of coagulability when the blood has been adequately ventilated by respiration in ordinary air (*vide* second oxygen inhalation in protocol of rabbit 155).

It evidently results from both these series of experiments that the diminution of carbonic acid in the blood which was assumed by me to afford a clue to the diminished coagulability of peptone[*] and of blood which has circulated through the lungs and heart alone is in reality capable of exercising a well marked retarding influence upon coagulation.

Effect of a Diminution of Oxygen.

It is extremely difficult to determine with precision what effect the withdrawal of oxygen exercises upon the coagulability of the blood. The difficulty consists in the complication of the phenomena which are due to the withdrawal of oxygen by other phenomena which are due to an increase of carbonic acid in the blood. To elucidate the matter, we evidently require methods which allow of at least a partial dissociation of the effects of the two gases. Such methods should aim at (*a*) a limitation of the amount of carbonic acid produced in the system after the oxygen is withdrawn; (*b*) the elimination of the carbonic acid which is produced; (*c*) a minimising of the effect of the carbonic acid increase. These objects can be partially realised by the two following methods :—

1. Inhalation of an atmosphere of indifferent gas (*e.g.*, hydrogen) while provision is made for free expiration into the external air.

This method provides to some extent for the elimination of the carbonic acid which is produced after the withdrawal of the oxygen. On the other hand, the method does not provide against the accumulation of carbonic acid which must occur during the dyspnœic stand-still of respiration.

2. Substitution of an atmosphere of unmixed carbonic acid for an atmosphere of carbonic acid and oxygen.

This method presents two advantages : (*a*) it limits the production of carbonic acid in the system, inasmuch as the withdrawal of oxygen, when made under these particular circumstances, no longer evokes any dyspnœic spasms ; (*b*) it minimises the effect of any increased carbonic acid tension inasmuch as such increase takes place in a blood which is already almost saturated with carbonic acid.

---

[*] 'Roy. Irish Acad. Proc.,' 3rd Series, vol. 2, No. 2, 1891; 'Roy. Soc. Proc.,' February, 1893.

1. *Results of Experiments in which Oxygen was withdrawn by the Substitution of Hydrogen for Atmospheric Air.*

I have employed this method in 29 experiments. In 15 of these experiments a diminution of coagulability was observed to result from the inhalation of hydrogen. In 14 other experiments an increase of coagulability was noted. With respect to the latter results, the following points are to be noted :—(*a*) The increase of coagulability was invariably confined within very moderate limits;* (*b*) in 2† out of the 14 experiments expiration was found to have been obstructed by an accidental compression of the tracheal tube.

The results of these experiments are patently ambiguous. On the one hand we have a bare majority of experiments or (if we subtract the experiments in which expiration was accidentally obstructed) a majority of only 15 to 12 experiments in favour of the result that the inspiration of hydrogen conditions a diminution, and not an increase, of blood coagulability. On the other hand, it is evident that there is nothing in these experiments when taken by themselves to justify a conclusion as to whether it is the decrease or the increase of coagulability which is to be regarded as the effect of the withdrawal of the oxygen. In such a case the only available method of interpretation consists in subducting from the aggregate of the observed phenomena such phenomena as we know by previous inductions to be the result of disturbing factors which cannot be eliminated from the experiments. The accumulation of carbonic acid in the blood, which occurs when the inevitable dyspnœic standstill of respiration takes place, or when (as in rabbit 176 and dog 4) expiration is accidentally obstructed, is just such a disturbing factor, and the effects of this disturbing factor must, in accordance with our previous inductions, manifest themselves in an increased blood coagulability. We may, therefore, legitimately assign to this cause all the phenomena of increased blood coagulability which came under observation in the hydrogen experiments. The residue of the observed phenomena, in other words the diminution of blood coagulability, then emerges as the effect of the absence of oxygen from the inspired air.

If the above train of argument is valid, we must conclude that the diminution of the oxygen of the blood conditions a diminution of coagulability.

---

* Coagulation-time was never found reduced below 1 minute 30 seconds (*vide* protocol rabbit 176). Coagulation-times of less than 1 minute are frequent (*vide* protocols *passim*) during inspiration of carbonic acid and oxygen.

† *Vide* protocols of rabbit 176 and of dog 4.

2. *Results of Experiments in which Oxygen was withdrawn by a Substi-*
tution of Unmixed Carbonic Acid for a Mixture of Carbonic Acid
and Oxygen.

This substitution of carbonic acid for the mixture of carbonic acid
and oxygen tends to effectuate itself spontaneously by the slowing
down and ultimate standstill of respiratory movements which super-
vene when an animal is continuously supplied with an atmosphere
surcharged with carbonic acid. A defect of oxygenation was allowed
to supervene in this manner in five* experiments. In all these cases
a diminution of coagulability was observed.

Similar experiments were performed by the actual substitution of
unmixed carbonic acid for an atmosphere of carbonic acid and
oxygen. In the four† experiments which were performed a diminu-
tion of coagulability was invariably observed.

The diminution of coagulability which is observed by either
variant of this method may be interpreted either (a) as an effect of
an excess of carbonic acid in the blood, or (b) as an effect of the
withdrawal of oxygen. Against the former interpretation of the
facts the following considerations may be urged : (1) the tension of
carbonic acid in the blood must already have been very high when
the substitution of gases was effected; (2) with the then obtaining
very slow respiratory movements the respiratory interchange in the
lungs must have been at a minimum. It is, therefore, unlikely that
any appreciable increase of carbonic acid tension can have effectuated
itself in the blood in the interval during which the lungs were filled
with unmixed carbonic acid.

If this reasoning is valid, we must evidently interpret the diminu-
tion of coagulability which came under observation in all these
experiments as a direct result of the withdrawal of the oxygen.

It need hardly be pointed out that this interpretation would
harmonise with the interpretation which has just been placed upon
the hydrogen experiments.

Effect of a Restoration of Oxygen to Blood rendered Anoxyhæmic by the
Inspiration of Hydrogen.

It may be premised that we have here, as in the case of the
hydrogen experiments, to disentangle the effects of a duplicated
series of phenomena, (a) the giving off of any excess of carbonic acid
which has accumulated in the blood, and (b) the restoration of
oxygen to the blood. The effect of (a) would, in accordance with
our previous‡ experiments, be a diminution of coagulability. On the

---

* Three of these experiments will be found on the protocols of rabbit 175, dog 3,
and rabbit 171.

† Two of these experiments will be found on the protocols of rabbit 175 and
rabbit 171.

‡ *Vide supra,* Experiments on Effect of Diminution of CO_2.

other hand, if the interpretation which we have placed upon the results of our experiments on the effect of a diminution of oxygen is correct, we should expect an increase of coagulability to accompany the restoration of oxygen to the blood.

The following is a summary of the results of the experiments which were directed to the determination of this point.

In a total of fourteen experiments, restoration of atmospheric air was in ten instances[*] found to result in an increase of coagulability. In the four remaining instances a decrease of coagulability was noted. It is, however, significant that in two of these instances the diminution of coagulability which was observed lay well within the limits of error of the method of determination, while in the remaining two instances[†] the diminution of coagulability was only a rebound from a condition of increased blood coagulability which was brought about by an accidental obstruction to the expiration of carbonic acid.

We may, therefore, conclude that the restoration of oxygen *to anoxyhœmic blood* conditions an increase of coagulability.

Comparison of the Results obtained above with the Results obtained by other Observers.

In recent times the question of the influence exerted by the blood gases on coagulation has been investigated among others by Vierordt,[‡] Hasebroek,[§] and Bonne,[||] and also by Mathieu and Urbain.[¶] The two first of these observers employed Vierordt's method of coagulability determinations, and both observers performed their experiments chiefly upon themselves. In none of their experiments does any attempt appear to have been made to dissociate the effect of changes in the quantity of carbonic acid in the blood from the effect of simultaneous changes in the quantity of oxygen in the blood. On the contrary, the phenomena which came under observation appear to have been referred to either one or other of these causes according to the particular bias of either observer. Thus Vierordt ascribes the increased coagulability which he detected in the stagnating blood of his ligatured finger to an increase in the CO_2 tension. On the other hand, Hasebroek, who reinvestigated this point, interprets the increased coagulability which is observed after a brief application of a ligature to the finger as an effect of a diminution of oxygen

* Examples of such increase of coagulability are given on protocols of rabbit 175, dog 4, rabbit 176, and rabbit 178.

† *Vide* third coagulation-determination on protocol of dog 4 and penultimate coagulation-determination on protocol of rabbit 176.

‡ *Loc. cit.*

§ 'Zeit. f. Biol.,' 1882.

|| 'Ueber das Fibrin-Ferment,' Würzburg, 1889.

¶ 'Comptes Rendus,' 1874, vol. 2, pp. 665 *et seq.*, and 698 *et seq.*

in the blood, while he ascribed the diminished coagulability which is observed after a lengthened application of the ligature to an excess of the carbonic acid. In like manner this observer ascribes (a) the increased coagulability which he obtained after holding his breath for twenty seconds to an increase of CO_2 in his blood, (b) the diminished coagulability he obtained after holding his breath for forty-five seconds to an excess of carbonic acid, (c) the diminished coagulability of venous, as compared with arterial, blood to the same cause, and (d) the diminished coagulability of his blood after rapid respiration to an excess of oxygen. There is nothing in the experiments to justify any of these inferences.

Exactly the same objections can be urged against Bonne's experiments. It will suffice to point out that Bonne obtained a diminution of coagulability in a bare majority of experiments in pigeons in which asphyxia was produced by the inspiration of carbonic acid, and that he interprets this diminution of coagulability as an effect of the excess of carbonic acid tension, while the anoxyhæmia to which the animals succumbed is entirely left out of sight as a possible factor in the causation.

Lastly, the work of Mathieu and Urbain comes up for notice. These observers conjointly investigated the effect of carbonic acid upon blood coagulability, and came to the conclusion that carbonic acid was a very important, if not indeed the all-important, agent in the production of blood coagulation. This conclusion was based upon the following observations : (a) Blood coagulation is accompanied by a giving off of something like 50 per cent. of the carbonic acid originally present in the blood ; (b) an artificial increase of the body temperature goes hand in hand with a diminution of the carbonic acid and with an increase in the oxygen in the blood, and this artificial increase of the body temperature results in a diminished coagulability ; (c) the blood from the renal vein, which resembles in its gaseous composition the blood of the superheated organism, is characterised by a similar diminished coagulability ; (d) an artificial reduction of the body temperature goes hand in hand with an increase of carbonic acid, which is quantitatively comparable to the increase which is produced by asphyxiating an animal by CO_2. This increase of carbonic acid in the blood under the influence of cold goes hand in hand with an increased blood coagulability ; (e) when blood is prevented from clotting by the addition of a few drops of ammonia (the ammonia is assumed to retard coagulation by binding the free carbonic acid), and when a new formation of carbonic acid is prevented by eliminating the oxygen from the blood by a stream of CO, the blood is found to have lost its spontaneous coagulability. Such blood becomes coagulable when a stream of CO_2 is passed through it ; (f) strong solutions of neutral salts have a large absorbing power for

free carbonic acid. The power which these solutions have of inhibiting blood coagulation is inferred to be associated with this property; (*g*) thrombosis of the pulmonary vessels occurs in dogs when they are caused to breathe atmospheric air in which the whole nitrogen has been replaced by CO_2; (*h*) after burns, the venous blood is found to contain a great excess of carbonic acid. The coagulability of such blood is abnormally high.

It will be observed that the experiments which have been the subject-matter of the present communication entirely confirm the conclusions which had already been arrived at by entirely different methods by Mathieu and Urbain. I have not in any systematic manner controlled the observations upon which the conclusions of these observers were based. I have, however, had many incidental opportunities of confirming their observations with respect to the alterations of blood coagulability which are conditioned by raising or cooling the general body temperature. On the other hand, I have not, in the very few cases I have examined for it, observed the occurrence of pulmonary thrombosis as an effect of a simple rise of carbonic acid tension in the blood, but I have, in one striking experiment, seen a rabbit whose blood coagulability had been increased by the administration of calcium chloride die instantaneously from universal intravascular coagulation, when it was supplied with an atmosphere which was surcharged with carbonic acid.

Appendix.   Selected Protocols.

The appended protocols are to be read from left to right, and then back in a zig-zag manner, following the dotted lines from right to left. In accordance with the fact that the method of coagulability determinations which was employed is an approximal and not an absolute one, two data are given for each coagulability determination. These data (longest interval during which the blood was observed to remain in a tube unclotted, and shortest interval which the blood was found to require for complete occlusion of a tube) are entered in separate columns. Where only a single entry appears on the protocols this is indicative of a lacuna in the observations. Thus, when an entry appears in the first column only (as, for instance, in the case of the second coagulability determination on the last protocol on the list), it is to be understood that the last of the coagulation tubes which were appropriated to the particular coagulability determination was found liquid when tested after the interval noted in the protocol. Similarly, when an entry appears in the second column only, as, for instance, in the second determination on the first protocol on the list, it is to be understood that all the tubes were found completely clotted, although the testing of the tubes was not deferred beyond the fifty seconds noted on the protocol.

Animal employed.	Atmospheric air. Interval between first inhalation of gas and filling of first coagulation tube. (m.)	Coagulation time longer than (m. s.)	Coagulation time shorter than (m. s.)	Hydrogen. Interval	longer than	shorter than	Oxygen. Interval (m.)	longer than (m. s.)	shorter than (m. s.)	Carbonic acid 80 per cent Oxygen 20 per cent. Interval (m.)	longer than (m. s.)	shorter than (m. s.)	Carbonic acid. Interval (m.)	longer than (m. s.)	shorter than (m.)	Remarks.
Rab-bit 125.	25'	2' 30", 1' 30"	2' 40", 2'				4'	1' 35"	2' 5"	4'	—	50"				
Rab-bit 158.	interval of 18 min	1'	1' 15"				—	2'	2'	3'	50"	55"				
	interval of 3 min.															
Rab-bit 161.	2', 10'	3' 40", 1' 15", 2' 30"	3' 45", 1' 15", 2' 45"							2', 4', 6', 10'	1' 15", 50", 2' 35", 35"	1' 30", 1', 1'	1'	2' 50"	3'	

Animal employed.	Atmospheric air. — Interval between first inhalation of gas and filling of first coagulation tube.	— Coagulation time longer than	— Coagulation time shorter than	Hydrogen. — Interval between first inhalation of gas and filling of first coagulation tube.	— Coagulation time longer than	— Coagulation time shorter than	Oxygen. — Interval between first inhalation of gas and filling of first coagulation tube.	— Coagulation time longer than	— Coagulation time shorter than	Carbonic acid 80 per cent. Oxygen 20 per cent. — Interval between first inhalation of gas and filling of first coagulation tube.	— Coagulation time longer than	— Coagulation time shorter than	Carbonic acid. — Interval between first inhalation of gas and filling of first coagulation tube.	— Coagulation time longer than	— Coagulation time shorter than	Remarks.
Rabbit 165.	m. Interval of 10 min.	m. s. 3' 30''	m. s. 3' 30''	m.	m. s.	m. s.	m. 4', 10'	m. s. 1' 40'', 3' 30''	m. s. 1' 45'', 4'	m. 2'; 3', 15', 35'	m. s. 3' 45''; 3', 3', 50''	m. s. 3'; 2' 30'', 2', 1'	m.	m. .	m. s.	Intestinal valve does not close air-tight, and admits some atmospheric air at each inspiration.
Rabbit 175.	m. 8', 15', 25'	m. s. 5' 30'', 2' 45'', 8', 4'	m. s. 5' 50'', 2' 45'', 3' 20'', 4' 30''	m. 50''	m. s. 4' 30''	m. s. 4' 30''				m. 3', 3'	m. s. —, 3'	m. s. 1', 2'	m. 3'	m. 4'	m. s. 4' 30''	

x 2

Animal employed.	Atmospheric air. Interval between first inhalation of gas and filling of first coagulation tube.	Coagulation time longer than	Coagulation time shorter than	Hydrogen. Interval between first inhalation of gas and filling of first coagulation tube.	Coagulation time longer than	Coagulation time shorter than	Oxygen. Interval between first inhalation of gas and filling of first coagulation tube.	Coagulation time longer than	Coagulation time shorter than	Carbonic acid 80 per cent. Oxygen 20 per cent. Interval between first inhalation of gas and filling of first coagulation tube.	Coagulation time longer than	Coagulation time shorter than	Carbonic acid. Coagulation time longer than	Coagulation time shorter than	Remarks.
Rab-bit 163.		m. s. 3' 30" interval of 2 min. interval of 5 min. interval of 1 min.	m. s. 2' 35"	m. 45" 45"	m. s. 1' 45" 2'	m. s. 1' 55" 2' 15"	m. 2'	m. s. 3' 40"	m. s. 3' 45"	m. 1' 5'	m. s. 2' 15" 1' 1' 10"	m. s. 1' 15" 1' 15"			
Rab-bit 149.		2' 45"	2' 45"							1' 5'	1' 45" —	2' 1' 15"			
Rab-bit 135.	interval of 25 min	2' 2' 15"	2'				—	5' 4' 15"	4' 4'	—	1' 25"	1' 40"			

Animal employed	Atmospheric air — Interval between first inhalation of gas and filling of first coagulation tube	Atmospheric air — Coagulation time longer than	Atmospheric air — Coagulation time shorter than	Hydrogen — Interval between first inhalation of gas and filling of first coagulation tube	Hydrogen — Coagulation time longer than	Hydrogen — Coagulation time shorter than	Oxygen — Interval between first inhalation of gas and filling of first coagulation tube	Oxygen — Coagulation time longer than	Oxygen — Coagulation time shorter than	Carbonic acid 80 per cent. Oxygen 20 per cent. — Interval between first inhalation of gas and filling of first coagulation tube	Carbonic acid 80 %/Oxygen 20 % — Coagulation time longer than	Carbonic acid 80 %/Oxygen 20 % — Coagulation time shorter than	Carbonic acid — Interval between first inhalation of gas and filling of first coagulation tube	Carbonic acid — Coagulation time longer than	Carbonic acid — Coagulation time shorter than	Remarks.
Dog 1.	m. 7	m. s. 10' 40" / 6' 30"	m. s. 10' 45" / 6' 45"	m. s.	m. s.	m. s.				m. 2' / 4'	m. s. 6' 25" / 8' 50"	m. s. 6' 30" / 2' 50"				In this and in the next two experiments the animal was supplied with a mixture of CO₂ and air.
Dog 2.	interval of 6 min. 12'	6' 30" / 8' 30"	6' 35" / 8' 40"	1' 30" / 1' 30"	5' 30" / 4'	5' 45"				4' / 6'	4' 53" / 3' 25"	4' 56" / 3' 30"				See remark to last experiment.
Dog 3.	8 / 10'	8' 30" / 4' 30"	9' 15" / 5' 30" / 1' 20'		4'	6' 55"				4' / 6'	1' 40" / 2'	1' 45" / 2' 15"				*Vide* remark to experiment with Dog 1.

Animal employed.	Atmospheric air. Interval between first inhalation of gas and filling of first coagulation tube.	Atmospheric air. Coagulation time longer than	Atmospheric air. Coagulation time shorter than	Hydrogen. Interval between first inhalation of gas and filling of first coagulation tube.	Hydrogen. Coagulation time longer than	Hydrogen. Coagulation time shorter than	Oxygen. Interval between first inhalation of gas and filling of first coagulation tube.	Oxygen. Coagulation time longer than	Oxygen. Coagulation time shorter than	Carbonic acid 80 per cent. Oxygen 20 per cent. Interval between first inhalation of gas and filling of first coagulation tube.	Coagulation time longer than	Coagulation time shorter than	Carbonic acid. Coagulation time longer than	Carbonic acid. Coagulation time shorter than	Remarks.
Dog 4.	m. 7′, 10′, 16′	m. 7′ 20″, 6′ 30″, 4′ 30″, 4′ 10″	m. s. 7′ 30″, 7′ 30″, 3′ 30″, 4′	m. s. 1′ 30″, 1′	m. s. 3′ 30″, 7′ 15″	m. s. 2′ 50″, 8′ 5″									Tracheal tube accidentally compressed during first hydrogen inhalation.
Rabbit 176.	m. 5′, 5′	m. 1′ 55″, 1′ 57″, 3′ 15″	m. s. 1′ 55″, 2′, 3′ 15″, 3′	m. s. 40″, 45″, 3′	m. s. 2′ 15″, 1′ 30″, 4′ 45″	m. s. 2′ 30″, 1′ 30″, 4′ 45″									Tracheal tube accidentally compressed during second hydrogen inhalation. Blood employed in penultimate coagulability determination was still very venous. Blood of last coagulability determination was obtained from right heart after death.

			Rabbit 171.	Rabbit 155.
Atmospheric air.	Interval between first inhalation of gas and filling of first coagulation tube.	m.		15' — interval of 8 min. — interval of 12 min. — interval of 30 min.
	Coagulation time longer than	m. s.	3' 15'' — 2' 30''	2' 30'' — 1' 30'' — 2'
	Coagulation time shorter than	m. s.	3' 15'' — 2' 40''	50'' — 2' 30'' — 2' 45''
Hydrogen.	Interval between first inhalation of gas and filling of first coagulation tube.	s.		50''
	Coagulation time longer than	m. s.		2' 30'' — 2' 30''
	Coagulation time shorter than	m. s.		2' 45''
Oxygen.	Interval between first inhalation of gas and filling of first coagulation tube.	m.		2' — 3'
	Coagulation time longer than	m. s.		— — 1' 45''
	Coagulation time shorter than	m. s.		1' 55'' — 2'
Carbonic acid 80 per cent. Oxygen 20 per cent.	Interval between first inhalation of gas and filling of first coagulation tube.	m. s.	8' — 15'	2' 30'' — 2'
	Coagulation time longer than	m. s.	2' 45' — 3'	— — 50''
	Coagulation time shorter than	m. s.	3' — 8' 45''	50'' — 55''
Carbonic acid.	Interval between first inhalation of gas and filling of first coagulation tube.			
	Coagulation time longer than	m. s.	4' 25''	
	Coagulation time shorter than	m. s.	4' 30''	
Remarks.			Blood employed in the penultimate coagulability determination was semi-venous in character.	

Animal employed.	Interval between first inhalation of gas and filling of first coagulation tube. (Atmospheric air)	Atmospheric air. Coagulation time longer than	Coagulation time shorter than	Interval between first inhalation of gas and filling of first coagulation tube. (Hydrogen)	Hydrogen. Coagulation time longer than	Coagulation time shorter than	Interval between first inhalation of gas and filling of first coagulation tube. (Oxygen)	Oxygen. Coagulation time longer than	Coagulation time shorter than	Interval between first inhalation of gas and filling of first coagulation tube. (Carbonic acid 80 per cent. Oxygen 20 per cent.)	Carbonic acid 80 per cent. Oxygen 20 per cent. Coagulation time longer than	Coagulation time shorter than	Interval between first inhalation of gas and filling of first coagulation tube. (Carbonic acid)	Carbonic acid. Coagulation time longer than	Coagulation time shorter than	Remarks.
Rabbit 178.	m. 6' 5' 5'	m. s. 6'15" 2'30" 2'35" 3'50"	m. s. 6'30" 2'30" 2'45" 4'15"	s. 40" 40" 40"	m. s. 6'30" 5' 3'55"	m. s. 6'30" 5'15" 3'55"										
Rabbit 172							m. 8' 11'	m. s. 3'45" 5'	m. 4' —	m. 10' 20' 35' 40' 55'	m. s. 3'15" 3'30" 40" 2'15" 4'15"	m. s. 3'54" 3'26" 50" 2'30" 4'55"				Expiration in this experiment took place into the reservoir (4000 c.c.) of oxygen. After the second co-agulability determina-tion was made, a stream of CO₂ was passed into the reser-voir so as gradually to replace the oxygen by carbonic acid. The last determination was made with blood ob-tained from the heart immediately after death.

Oxygen decreasing from 100 per cent. CO₂ increasing from 0 per cent.

Death. 4'55" 4'55"

IX. " On the Disappearance of the Leucocytes from the Blood, after Injection of Peptone."   By Surgeon-Captain DAVID BRUCE, A.M.S., Army Medical School, Netley.   Communicated by Professor HORSLEY, F.R.S.   Received February 21, 1894.

As is well known, the injection of a solution of peptone into the circulation of certain animals is followed immediately by a very considerable diminution in the number of white blood corpuscles in the circulating blood.   Some investigators who have written on this subject ascribe this diminution to the destruction and breaking down of the leucocytes in the blood plasma.

As this theory appeared to me to rest on the very slenderest evidence, and as it seemed to me much more natural to believe that a temporary withdrawal of the leucocytes into the internal organs took place, I was led to attempt the enumeration of the white blood corpuscles in sections of the various organs before and after the injection of peptone.

If the theory of destruction is true, then the leucocytes ought to be found in fewer numbers in the organs as well as in the blood, whereas, if the theory of temporary withdrawal be the true one, then an augmentation in their number should be seen in the sections.

For the purpose of this enumeration I used rabbits of equal weight, and proved to have a normal number of white blood corpuscles by examination of samples of blood taken from the ear.

Six rabbits were taken.   The organs of two of these were examined without previous injection of peptone.   The third, with a normal number of white blood corpuscles, was killed $3\frac{1}{2}$ hours after the injection of the peptone solution, when $\frac{4}{5}$-ths of the white blood corpuscles had disappeared from the circulating blood.

The fourth, also having a normal number of white blood corpuscles, was killed 5 seconds after injection, when almost all the leucocytes had disappeared, at least from the blood of the heart.

In the fifth and sixth a leucocytosis was first caused by the injection of appropriate fluids and the animals killed 5 seconds after the injection of peptone.

As it seemed to me impossible to be certain of recognising all the varieties of the leucocytes in sections of the organs, I restricted myself to enumerating what I know as the polynuclear variety, since this is the variety which disappears most completely from the blood after the injection of peptone and many other substances, and which can be very readily recognised in sections after appropriate staining.

I may mention here that for practical purposes and without pre-judice as to their origin, I adopt the classification of the leucocytes of the rabbit's blood into four varieties :—

A. The Eosinophilous, constituting on an average 2 per cent. of the total leucocytes, with an irregular-shaped nucleus and large oval shaped granules, which stain readily in eosine.

B. The Polynuclear, 51 per cent., with intensely staining poly-morphous nucleus, having the appearance of several nuclei united by narrow thread-like processes, the protoplasm of the cell containing fine granules which also stain in eosine.

C. The Myelocytes, 16 per cent. Difficult in every case to rigidly separate from the fourth variety, but defined as mononuclear cells, the nucleus of which stains badly, and is surrounded by compara-tively a large amount of non-granular protoplasm.

D. The Lymphocytes, 31 per cent. Mononuclear cells, little larger than a red blood corpuscle, with intensely staining nucleus and narrow rim of protoplasm.

The preliminary enumeration of the leucocytes in the blood of the ear or heart was made by diluting the blood 200 times with an 8 per cent. magnesium sulphate solution, to which sufficient gentian violet had been added to stain the white blood corpuscles, and not by estimating their proportion to the red blood corpuscles, which seems to me a most unsound method. The number of white blood cor-puscles in 300 squares of a Gower's hæmocytometer were then counted and this number multiplied by 333, which gives approxi-mately the number in a cubic millimetre.

Three samples of blood are taken, two of which are counted, and, if the counts are sufficiently close, an average made. In the event of there being a marked discrepancy, the third sample is counted and an average of the two most alike taken, but, with care, it is seldom found necessary to use the third sample.

In regard to the fixing and hardening of the tissues for cutting, alcohol, Müller's solution, Foa's, and Flemming's solutions were used, but the best results were obtained by fixing for twenty-four hours in Flemming's strong solution, washing in running water for twenty-four hours, then through successive alcohols for forty-eight hours.

The tissues, after infiltration with paraffin, were cut as neatly as possible of the same thickness, and stained in various ways, the most successful results being got by staining for twenty-four hours in the Ehrlich-Biondi triple stain.

On taking the sections out of the stain I place them for a minute in a saturated solution of corrosive sublimate, as this seems in some way to prevent them becoming too much decolorised during the sub-sequent manipulations.

The white blood corpuscles contained in twenty fields of the micro-

scope (Zeiss' 2 millimetres apochromatic, oil immersion, and 8 eye-piece) were counted in each section, several of which were mounted from each organ, and, as will be seen, with very striking uniformity of results.

I shall now proceed to describe the results obtained in each experiment.

No. 1. *Control Experiment.*—Rabbit, weight 2 kilos. The blood from an ear-vein was found to contain 6500 leucocytes per cubic millimetre—0 per cent. eosinophilous, 34 per cent. polynuclear, 20 per cent. myelocytes, 46 per cent. lymphocytes—of which 2210 were thus polynuclear. The animal was now killed by a blow on the head and the organs at once removed. Four sections of the spleen were found to contain 54, 47, 55, and 54 polynuclear leucocytes respectively (twenty fields of the microscope being counted in each specimen), the lung, 39 and 32, and the liver, 7, 6, and 7.

It will be seen from the above enumerations that a remarkable uniformity was found to exist in the distribution of the polynuclear leucocytes in different sections of the same organ. This, I may here mention, obtained throughout, not only in the control experiments, but also after the injection of peptone.

No. 2. *Control Experiment.*—Rabbit, 2 kilos. The blood from an ear-vein was found to contain 3833 polynuclear leucocytes in each cubic millimetre. Two sections of the spleen were counted and contained, in 20 fields, 62 and 74 respectively; the lung, 35 and 41 ; liver, 5 and 6.

No. 3. *Control Experiment.*—To show that the blood contained in the right and left ventricles does not differ markedly from the blood taken from an ear-vein in the number of leucocytes contained in the cubic millimetre the following experiment was made :—

Rabbit, 2 kilos. The blood from an ear-vein was found to contain 8500 leucocytes in each cubic millimetre. After an hour the rabbit was killed by a blow on the head, and the heart ligatured and removed as soon after death as possible.

The blood of the right ventricle was found to contain 7200 leucocytes per cubic millimetre ; that of the left, 7500.

The following experiment shows the number of polynuclear leucocytes found in sections of the organs of an ordinary normal rabbit after the leucocytes have been greatly diminished in the circulating blood by the injection of peptone.

No. 4. Rabbit, 2 kilos. Blood from the right ear contained 4015 polynuclear leucocytes. Three and a half hours after the injection into a vein of the left ear of 3·5 grams peptone, dissolved in 35 c.c. water, blood from the right ear only contained 1100 of the same variety.

Sections of the spleen prepared and examined in the same way as

in Experiments 1 and 2, contained 159, 150, 171, and 168 polynuclear leucocytes in 20 fields of the four specimens examined; the lung, 230 and 209; the liver, 38 and 35 respectively.

This experiment then shows a large increase in the number of the polynuclear leucocytes in the organs, as compared with what was found in the organs of the control animals.

But, as the injection of peptone causes not only a primary diminution but also a secondary augmentation in the number of leucocytes in the blood, it might be argued that this augmentation takes place at first in the organs, and that this might account for the increase found in Experiment No. 4.

To meet this objection the following experiment was made :—

No. 5. Rabbit, 2 kilos. Blood from ear contained 9200 leucocytes, of which 47 per cent. or 4424, belonged to the polynuclear variety; 20 c.c. of a 10 per cent. peptone solution were now rapidly injected into the left jugular vein, and the animal killed five seconds after the injection.

The blood contained in the heart was at once examined, that in the left ventricle being found not to contain a single leucocyte of any kind whatever; that of the right only 166 per cubic millimetre, all told. It must be noted, however, that the leucocytes do not disappear from all parts of the circulation with this marvellous rapidity, as Experiment No. 7 will show.

The organs in this case were also found to contain a great excess of polynuclear leucocytes: the spleen, 174, 133, and 149; the lung, 230 and 221; the liver, 12 and 14.

I next tried the effect of first causing a leucocytosis, and then driving the white blood corpuscles out of the blood by peptone, in the belief that some proportionate increase in the number of the polynuclear leucocytes in the organs might be found.

No. 6. Rabbit, weight 2 kilos. Blood from ear contained 7800 leucocytes, of which 4290 belonged to the polynuclear variety.

Nineteen hours after the injection of 10 c.c. of a broth cultivation of anthrax, which had been sterilised by filtration through a Chamberland filter, the number of leucocytes in the blood taken from the ear had increased to 17,600, of which 11,264 were polynuclear. 20 c.c. of a 10 per cent. peptone solution were now injected into the jugular vein, and, five seconds afterwards, the animal killed. Blood from the left ventricle contained no leucocytes; that from the right ventricle only 1500 per cubic millimetre.

The spleen sections contained 223 and 218, the lung 251 and 247, the liver 12 and 10.

Experiment 7. Rabbit, 2 kilos. The blood taken from an ear-vein contained 14,300 white-blood corpuscles.

20 c.c. of a 10 per cent. peptone solution were injected into an

ear-vein, and, five seconds afterwards, the white-blood corpuscles in the opposite ear enumerated, when no diminution in their number was found.   Eighteen hours after the injection an intense leucocytosis was found to have become developed, no fewer than 184,500 white blood corpuscles being found in each cubic millimetre of blood drawn from the ear.

Again, 20 c.c. of a 10 per cent. peptone solution were injected; this time by the left jugular vein, and, five seconds afterwards, the animal killed.   The blood in the left ventricle contained 1000 white blood corpuscles per cubic millimetre, the right ventricle 3000, and the inferior vena cava in the lumbar region 5000.

Sections of the spleen contained 262 and 308, the lung 435, 325, and 348, and the liver 78 and 82.

Presenting, for the sake of clearness, the above facts in a tabular form, an average of the various numbers being set down, the contrast is striking.

Organs examined.	Control experiment.	Control experiment.	Normal rabbit, 3½ hours after injection of peptone.	Normal rabbit, 5 seconds after injection of peptone.	Rabbit with slight leucocytosis after injection of peptone.	Rabbit with intense leucocytosis after injection of peptone.
Spleen......	52	78	160	152	290	295
Lung........	39	38	214	225	249	369
Liver.......	6	5	36	18	11	80

From the above table it is seen that the lung harbours a greater proportion of the leucocytes which have disappeared from the blood than any other organ.   This may be accounted for by the fact that this organ is the first acted on by the peptone solution after its injection into the jugular vein.

Other organs, such as the kidney, supra-renals, and ovary, were found to contain so few leucocytes, either before or after the injection of peptone, that the results as regards them have been neglected.

I conclude from the above experiments that the injection of a solution of peptone into the circulation of rabbits does not cause, as has been asserted, a destruction of leucocytes, but merely a withdrawal of them into various organs, notably the lungs and spleen.

The Society then adjourned over the Easter Recess to Thursday, April 19.

Presents, March 15, 1894.

Transactions.

Berlin:—Gesellschaft für Erdkunde. Verhandlungen. Bd. XXI.
    No. 1. 8vo. *Berlin* 1894.   The Society.

Bordeaux:—Société de Médecine et de Chirurgie. Mémoires et
    Bulletins. 1892. Fasc. 3—4. 1893. Fasc. 1—2. 8vo.
    Bordeaux 1893-94.   ·   The Society.

Brüun:—Naturforschender Verein. Verhandlungen. Bd. XXXI.
    8vo. *Brünn* 1893; Bericht der Meteorologischen Commis-
    sion. No. 11. 8vo. *Brünn* 1893.   The Society.

Cambridge, Mass.:—Harvard College. Annual Reports of the
    President and Treasurer. 1892-93. 4vo. *Cambridge* 1894.
                                                       The College.

Catania:—Accademia Gioenia di Scienze Naturali. Atti. Anno.
    LXX. 4to. *Catania* 1893; Bullettino. Fasc. 33-35. 8vo.
    Catania 1893.   The Academy.

Kazan:—Imperial University. [Two Medical Dissertations.]
    [*Russian.*] 8vo. *Kazan* 1893.   The University.

Kew:—Royal Gardens. Bulletin of Miscellaneous Information.
    1894. No. 87. 8vo. *London.*   The Director.

Leipsic:—Königl. Sächs. Gesellschaft der Wissenschaften. Berichte
    über die Verhandlungen (Math.-phys. Classe). 1893. Hefte
    7-9. 8vo. *Leipzig* 1894.   The Society.

London:—Geologists' Association. Proceedings. Vol. XIII.
    Part 6. 8vo. *London* 1894.   The Association.

Photographic Society of Great Britain. Journal and Transac-
    tions. Vol. XVIII. No. 4. 8vo. *London* 1893.
                                                       The Society.

Society of Biblical Archæology. Proceedings. Vol. XVI.
    Part 4. 8vo. *London* 1894.   The Society.

Paris:—École Normale Supérieure. Annales. Tome XI. No. 1.
    4to. *Paris* 1894.   The School.

Rotterdam:—Bataafsch Genootschap der Proefondervindelijke
    Wijsbegeerte. Verhandelingen. Reeks 2. Deel IV. Stuk 1.
    4to. *Rotterdam* 1893.   The Society.

Santiago:—Sociedad Nacional de Mineria. · Boletin. Año X. No.
    62. 4to. *Santiago de Chile* 1893.   The Society.

Vienna:—K. K. Geologische Reichsanstalt. Verhandlungen. 1893.
    Nos. 15-18. 8vo. *Wien* 1893.   The Institute.

Washington:—U. S. Department of Agriculture. Experiment
    Station Record. Vol. V. No. 5. 8vo. *Washington* 1894.
                                                       The Department.

Observations and Reports.
>   Calcutta:—Meteorological Department, Government of India.
>   Meteorological Observations recorded at Seven Stations in
>   India. September, 1893. 4to.; Monthly Weather Review.
>   September, 1893. 4to. *Calcutta* 1894. The Department.
>   Sydney:—Observatory. Meteorological Observations. September,
>   1893. 8vo. The Observatory.

Journals.
>   Annaes de Sciencias Naturaes. Anno. I. No. 1. 8vo. *Porto*
>   1894. The Editor.
>   Revue Médico-pharmaceutique. Année VII. No. 1. 4to. *Con-*
>   *stantinople* 1894. The Editor.
>   Technology Quarterly. Vol. VI. No. 3. 8vo. *Boston* 1893.
>   Massachusetts Institute of Technology.

Hale (G. E.) The Solar Faculæ. 8vo. *London* 1894.
>   The Author.
[Marshall (A. M.), F.R.S.]. [Biographical Notices. 8vo. *Bir-*
>   *mingham* 1894]. Mr. W. P. Marshall.
Schück (A.) Magnetische Beobachtungen an der Unterelbe, ange-
>   stellt im Jahre 1893. 8vo. *Hamburg* 1894. The Author.
Vogel (H. C.) Über das Spectrum von β Lyrae. 8vo. *Berlin*
>   1894. The Author.

Photograph of the Indenture of Sir H. Davy, in the possession of
the Royal Institution of Cornwall. Mr. John D. Enys.

Account of the appropriation of the sum of £4,000 (the Govern-
ment Grant) annually voted by Parliament to the Royal
Society, to be employed in aiding the Advancement of
Science (continued from vol. liii, p. 321).

April 1, 1893, to March 31, 1894.

GENERAL FUND.

	£	s.	d.
A. M. W. Downing, for the Expense of Computations for a New Edition of Taylor's Madras Catalogue of Stars	100	0	0
Carried forward	£100	0	0

	£	*s.*	*d.*
Brought forward	100	0	0
W. G. Rhodes, for a Minute Study of the Electrical Temperature Coefficient of some Pure Metals, with the view of obtaining an Electrical Thermometer more reliable than the Platinum Thermometer	35	0	0
W. S. Wilson, to Make and Experiment with an Instrument which is designed to find the Direct Intensity of Solar Radiation	30	0	0
Dr. S. Young, for the Determination of the Vapour Pressures and Molecular Volumes, both as Liquid and Saturated Vapour, of various Substances, from Low Temperatures to their Critical Points	40	0	0
Dr. Edridge Green, for Continuation of his Experiments on Colour-blindness	60	0	0
Prof. C. V. Boys, for a Research on the Constant of Gravitation γ by a very Exact Method depending on the use of Quartz Fibres	50	0	0
G. Higgs, for Completing and Printing a Photographic Atlas of the Normal Solar Spectrum............	50	0	0
Dr. Schuster, for Assistance in Certain Numerical Calculations concerning Terrestrial Magnetism	50	0	0
E. H. Griffiths, for (1) a Comparison of Air, Mercury, and Platinum Determinations of Temperature; (2) Continuation of Investigation into the Capacity for Heat of Water at Different Temperatures............	60	0	0
A. Mallock, for the Measurement of the Constant of Viscosity of Fluids, and the Examination of the Conditions which lead to Instability in the Flow of Fluids past Solid Obstacles.............................	50	0	0
A. J. Herbertson, for an Investigation into the Hygrometry of the Atmosphere at Different Altitudes	100	0	0
C. T. Heycock and F. H. Neville, for Continuation of Experiments on Solutions of Metals in Metals........	70	0	0
J. Walker, for an Investigation of the Affinity of Weak Acids and Bases.........................	20	0	0
S. U. Pickering, for further Research on the Nature of Solutions	50	0	0
W. P. Bloxam, for an Examination of the Compounds formed by Ammonium with Sulphur................	50	0	0
S. E. Linder and H. Picton, for an Investigation into the Connection between different Grades of Solution	20	0	0
Carried forward........	£835	0	0

	£	s.	d.
Brought forward	835	0	0
W. H. Perkin, jun., for an Investigation into the Constitution of Camphoric and Allied Acid	75	0	0
Dr. Tilden, towards defraying Expenses incurred in a Systematic Examination of the Action of Nitrosyl Chloride upon Carbon Compounds..................	50	0	0
H. B. Baker, for the Full Investigation of the Influence of Moisture on Various Types of Chemical Actions	120	0	0
Dr. Japp, for an Investigation of the Reactions of Ketones, Diketones, and Allied Compounds..........	75	0	0
S. F. Dufton, for a Research on the Hydrazines of Quinoline	50	0	0
E. P. Perman, for Continuation of a Research on Vapour Density.................................	20	0	0
W. A. Shenstone, for Continuing the Investigation of the Influence of Silent Discharge of Electricity on Oxygen and other Gases	30	0	
G. T. Moody, for the Study of Phenanthrene	50	0	0
F. S. Kipping, for the Preparation and Study of Cyclic Keto-derivatives, more especially those of Interest in relation to Camphor.......................	60	0	0
The Pharmacological Committee (per Prof. Dunstan), for Pharmacological Investigations with Chemically Pure Substances of Ascertained Composition	200	0	0
J. T. Hewitt, for a Research on Ortho-substituted Phenyl-hydrazines........................,.......	20	0	0
C. Davison, for the Investigation of British Earthquakes.......................................	25	0	0
J. H. Cooke, for an Investigation of the Nature, Distribution and Fauna of the Pleistocene Deposits of the Maltese Islands	50	0	0
Herbert Bolton, for an Investigation into the Age, Stratigraphy, and possible Fossil Contents of the Skiddaw Slates of the Isle of Man...................	20	0	0
R. Kidston, to Work out the Vertical and Horizontal Distribution of the British Carboniferous Flora	40	0	0
G. F. Scott-Elliot, for an Expedition to Investigate the Flora, Fauna, and Geology of Tanganyika, Uganda, &c.......................................	700	0	0
Bahamas Committee (per W. T. T. Dyer), for the Botanical Exploration of the Bahamas	150	0	0
Carried forward..........	£2,570	0	0

	£	s.	d.
Brought forward	2,570	0	0
West India Committee (per G. Murray), to continue the Work of the Joint Committee of the Royal Society and British Association for the Exploration of the Natural History of the West India Islands	100	0	0
Liverpool Marine Biology Committee (per W. Herdman), for the further Exploration of the British Marine Fauna, especially in the neighbourhood of Liverpool and the shores of the Isle of Man	50	0	0
E. J. Allen, for a Research on the Later Stages in the Development of Decapod Crustacea	200	0	0
Sandwich Islands Committee (per Dr. Sharp), for the Investigation of the Fauna of the Hawaiian Islands ..	200	0	0
Prof. J. R. Ainsworth Davis, for a Research on the " Locality Sense " in *Patella vulgata*	20	0	0
E. J. Bles, for further Research on the Marine Floating Organisms of the British Seas, and the effect of Changes of Environment on their Distribution........	50	0	0
Dr. A. B. Harris, for the Investigation of Oxidation and Reduction Processes in Animals under various Pathological Conditions	20	0	0
W. M. Bayliss, on the Nature of the Action of the Vasomotor Centre	40	0	0
C. A. Ballance and S. Shattock, for a Research on the Intimate Pathology of Cancer	50	0	0
Dr. E. H. Starling, for a Research on the Physiology of Lymph Secretion	50	0	0
Dr. A. E. Garrod, for further Research on certain of the Urinary Pigments, and other Allied Investigations......................................	20	0	0
Prof. P. F. Frankland, for Continuation of Researches on the Chemical Changes induced by Specific Micro-organisms	125	0	0
C. S. Sherrington, for the Examination of the Actions and the Topography of Reflex and Automatic Centres in the Lower Half of the Spinal Cord...............	50	0	0
W. G. Spencer, for a Research on the Central Innervation of the Respiration and Circulation in connexion with Increased Intra-cranial Pressure, &c.	75	0	0
Prof. W. D. Halliburton, for Researches on (1) Intravascular Coagulation (2) the Nutrition value of Hæmoglobin	50	0	0
Carried forward	£3,670	0	0

	£	s.	d.
Brought forward	3,670	0	0
Dr. Copeman, for further Aid iu Researches on the Bacteriology of Vaccine Lymph	50	0	0
Joint Eclipse Committee, towards excess of Expenditure over Estimates. ....,....	100	0	0
	£3,820	0	0

General Fund.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance, March 31, 1893	845	7	9	By Appropriations, as above	3,820	0	0
„ Parliamentary Grant	4,000	0	0	„ Salaries, Printing, Postage, Advertising, and other Administrative ·Expenses	108	7	0
„ Repayment.................	70	7	0				
„ Interest on Deposit.........	27	17	0				
				„ Transferred to Reserve Fund	500	0	0
				„ Balance, Mar. 31, 1894	515	4	9
	£4,943	11	9		£4,943	11	9

Reserve Fund.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance, Mar. 31, 1894.	900	0	0	By Balance, Mar. 31, 1894	1,400	0	0
„ Transfer from General Fund................	500	0	0				
	£1,400	0	0		£1,400	0	0

Report of the Incorporated Kew Committee for the Year ending December 31, 1893.

The operations of The Kew Observatory, in the Old Deer Park, Richmond, Surrey, are controlled by the Incorporated Kew Committee, which is constituted as follows :—

Mr. F. Galton, *Chairman.*

Captain W. de W. Abney, C.B., R.E.

Prof. W. G. Adams.

Captain E. W. Creak, R.N.

Prof. G. C. Foster.

Admiral Sir G. H. Richards, K.C.B.

The Earl of Rosse, K.P.

Prof. A. W. Rücker.

Mr. R. H. Scott.

Lieutenant-General R. Strachey, C.S.I.

General J. T. Walker, C.B.

Captain W. J. L. Wharton, R.N.

On February 9 the Kew Committee became registered under the Companies Acts, 1862 and 1867, as the " Incorporated Kew Committee of the Royal Society."

The Memorandum and Articles of Association are given in Appendix A.

It is with deep regret that the Committee have to report the decease of the late Superintendent of the Observatory, Mr. G. M. Whipple, B.Sc., which occurred on the 8th of February, after a serious illness of more than seven months. He had been connected with the Observatory in various capacities for thirty-four years, and had filled the office of Superintendent since 1876. Under his efficient management the work at the Observatory had been largely augmented in amount and variety, and the funds at its disposal for purchase of apparatus and extension of its premises had steadily increased. Mr. Whipple was the author of numerous papers on Meteorological and other subjects connected with the work of the Observatory, which appeared in the ' Proceedings of the Royal Society,' the ' Quarterly Journal of the Royal Meteorological Society,' and other scientific publications.

During the year there also occurred the death of Mr. H. McLaughlin, Librarian and Accountant, whose connexion with the Observatory had extended over twenty years.

The Committee having invited applications for the vacant post of Superintendent, selected from amongst the candidates Mr. Charles Chree, M.A., Fellow of King's College, Cambridge, Sixth Wrangler 1883, First Division Part III of the Mathematical Tripos, and First Class in Part II of the Natural Sciences Tripos, 1884. Mr. Chree entered on his duties on May 15.

During the earlier part of the year the work of the Observatory was carried out by Mr. Baker, the Chief Assistant, to the entire satisfaction of the Committee. They desire that his services should be specially recorded, and they are glad to state that the routine work of the Observatory has in no way suffered owing to the enforced absence of the Superintendent for the early months of the past year.

The work at the Observatory may be considered under the following heads:—

1st. Magnetic observations.
2nd. Meteorological observations.
3rd. Solar observations.
4th. Experimental, in connexion with any of the above departments.
5th. Verification of instruments.
6th. Rating of Watches and Marine Chronometers.
7th. Miscellaneous.

I. Magnetic Observations.

The magnetographs have been in constant operation throughout the year, and the scale values of all the instruments were determined in January.

The ordinates of the various photographic curves were then found to be as follows :—

Declinometer: 1 inch = 0° 22'·04. 1 cm. = 0° 8'·7.

Bifilar, January 18, 1893, for 1 inch δH = 0·0274 foot grain unit.
 „ 1 cm. „ = 0·00050 C.G.S. unit.
Balance, January 19, 1893, for 1 inch δV = 0·0277 foot grain unit.
 „ 1 cm. „ = 0·00050 C.G.S. unit.

The distance between the dots of light upon the Vertical Force cylinder having become too small for satisfactory registration, the position of the zero dot was altered on January 23.

The toothed wheel of the Declination cylinder being much worn,

a new one was obtained from Adie, London, and fitted to the cylinder on July 5.

On August 10 the clock was dismounted and cleaned.

As regards Magnetic Disturbances, no very large movements have been registered during the year. The principal oscillations that were recorded took place on the following days :—

February 4—5, March 14—15, April 26, June 18—19, July 16, August 6—7 and 18, November 1—2.

The hourly means and diurnal range of the magnetic elements for 1893, for the quiet days selected by the Astronomer Royal, will be found in Appendix I.

The following are the mean results for the entire year :—

Mean Westerly Declination .... 17° 28'·8
Mean Horizontal Force............ .0·18238 C.G.S. units.
Mean Inclination .... 67° 26'·3
Mean Vertical Force .... 0·43896 C.G.S. units.

The observations of Horizontal Force, Inclination, and Declination with the absolute instruments have been made in accordance with the usual practice.

Captain Schück visited the Observatory in July, and made a series of absolute magnetic observations in order to compare his own instruments with those of Kew, prior to his continuing his magnetic survey on the banks of the Elbe.

The temperature coefficients of the magnets employed by Captain Schück were determined at Kew.

The magnetic instruments have been studied and a knowledge of their manipulation obtained by Lieutenants Parry and Tancred, of the Royal Navy, who visited the Observatory from December 4 to December 20.

II. METEOROLOGICAL OBSERVATIONS.

The several self-recording instruments for the continuous registration respectively of Atmospheric Pressure, Temperature of Air and Wet-bulb, Wind (direction and velocity), Bright Sunshine, and Rain, have been maintained in regular operation throughout the year, and the standard eye observations for the control of the automatic records duly registered.

The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud, and sunshine, have been transmitted, as usual, to the Meteorological Office.

A summary of the results for the year is given in Appendix II, Tables I, II, and III.

With the sanction of the Meteorological Council, data have been supplied to the Council of the Royal Meteorological Society, the Institute of Mining Engineers, the editor of 'Symons's Monthly Meteorological Magazine,' Dr. Rowland, and others.

Detailed information of thunderstorms observed in the neighbourhood during the year has been forwarded to the Royal Meteorological Society.

Anemograph.—The "worm" on the direction fan-spindle had become very thin through wear, causing considerable "back-lash;" a new one has been put in hand by Munro, and will be fitted up at an early date.

The new square-headed pricker, mentioned in the last Report, has been rather unsatisfactory in its action, and will be shortly replaced by a round one, made of specially hardened steel.

Rain-gauge.—The Willesden prepared papers have been in daily use on the self-recording Beckley gauge, and although the curves obtained are clear and distinct, yet the defect of the lengthening of the sheets in wet weather has not been entirely overcome.

Circular letters were sent to several prominent paper makers asking for samples of material, specially prepared, to be used in a very damp atmosphere; but of those thus obtained, only one sample (supplied by Messrs. Waterlow and Sons) showed no appreciable lengthening in the dampest atmosphere producible artificially. It has, however, some counterbalancing defects, which render its superiority to the Willesden paper for the purpose in view somewhat doubtful.

Barograph.—At the request of the Meteorological Office an investigation has been carried out as to the causes of fluctuations that present themselves in the value of the residual correction to the barograph readings, which is deduced by comparison of simultaneous readings of the barograph and a standard barometer.

An analysis was made of the value of the residual correction between May, 1892, and October, 1893, while numerous measurements were taken of the width of the temperature compensation to the barogram at different temperatures. The data obtained accounted for a very considerable part, at least, of the irregularities observed in the residual correction.

A report embodying an analysis of the results has been sent to the Meteorological Office.

Electrograph.—This instrument has been in regular action during the year, but its performance on the whole has been rather unsatisfactory. Early in the year the needle-suspension being accidentally broken, another was fitted without delay, and a new determination

made of the scale value. Subsequent re-determinations were carried out in May, July, and November.

It is intended to take advantage of the first spell of frosty weather to dismount and thoroughly overhaul the instrument, and to open out the scale, which has for some time past been too contracted.

Inspections.—In compliance with the request of the Meteorological Council, Mr. Baker visited and inspected the Observatories at Stony-hurst, Glasgow, Fort William, and Aberdeen, and the Anemograph Stations at Yarmouth, North Shields, Alnwick Castle, Deerness (Orkney), Fleetwood, and Holyhead; while Mr. Constable inspected the Observatories at Oxford and Falmouth.

III. Solar Observations.

Sun-spots.—Sketches of Sun-spots have been made on 155 days, and the groups numbered, after Schwabe's method.

Particulars will be found in Appendix II, Table IV.

The marked exhibition of solar activity noted in last report has continued, and although no phenomenally large group of Sun-spots has appeared, yet no one observation has been recorded in which the Sun's surface was entirely free from spots.

Time Signals.—These have been regularly received from Greenwich through the G.P.O., with the exception of a few days, on which occasions supplementary signals were transmitted at later hours.

IV. Experimental Work.

Richard's Anemo-cinemograph.—This instrument, which has been at the Observatory since May, 1891, was at the end of the year returned to Mr. Casella, by request of the makers.

Cloud Photographs.—Operations connected with cloud photography have been suspended during the past year.

Fog and Mist.—The observation of a series of distant objects referred to in the last report has been continued. A note is taken of the most distant of the selected objects which is visible at each observation hour. An analysis of the results for the period May, 1892, to December, 1893, is at present being carried out.

During the thickest fog experienced in the past year, at one of the hours of observation the most distant object visible was only 12 feet off.

V. Verification of Instruments.

The subjoined is a list of the instruments examined in the year 1893, with the corresponding results for 1892:—

| | Number tested in the year ending December 31. | |
	1892.	1893.
Air-meters	9	15
Anemometers	4	24
Aneroids	74	59
Artificial horizons	22	15
Barometers, Marine	74	98
„ Standard	61	50
„ Station	18	30
Binoculars	168	466
Compasses	28	12
Deflectors	20	4
Hydrometers	395	591
Inclinometers	1	2
Photographic Lenses	18	31
Magnets	1	3
Navy Telescopes	487	913
Rain Gauges	9	19
Rain Measures	13	37
Sextants	463	517
Sextant Shades	52	47
Sunshine Recorders	1	1
Theodolites	6	2
Thermometers, Arctic	50	44
„ Avitreous or Immisch's	71	54
„ Chemical	44	57
„ Clinical	16,850	14,682
„ Deep sea	31	69
„ Meteorological	1,875	2,246
„ Mountain	17	18
„ Solar radiation	1	2
„ Standard	79	88
Unifilars	1	1
Vertical Force Instruments	5	0
Total	20,948	20,197

Duplicate copies of corrections have been supplied in 19 cases.

The number of instruments rejected on account of excessive error, or for other reasons, was as follows :—

Thermometers, clinical	57
„ ordinary meteorological	16
Sextants	109
Telescopes	119
Various	18

3 Standard Thermometers have been supplied during the year.

There were at the end of the year in the Observatory undergoing verification, 6 Barometers, 571 Thermometers, 18 Sextants, 45 Telescopes, and a Sunshine Recorder.

VI. Rating of Watches and Chronometers.

A large increase has taken place in the number of watches sent for trial during the year, 1,521 having been received, as compared with 1,044 during the previous twelve months.

This increase, however, has been largely in watches entered for the class B test, and for various reasons a future falling off in the number of such watches is not unlikely.

It is a gratifying fact that the number of high-class movements attaining the distinction *especially good* has been greater than in any previous year.

The watches were entered for trial as below :—

For class A, 376; class B, 885; class C, 251; and 9 for the subsidiary trial. Of these 5 passed the subsidiary test, 299 failed from various causes to gain any certificate; 238 were awarded class C certificates, 722 class B, and 257 class A; of the latter, 34 obtained the highest form of certificate, class A, *especially good.*

In Appendix III will be found a table giving the results of trial of the 34 watches which gained the highest number of marks during the year. The first place was taken by Messrs. Stauffer, Son, and Co., London, with a keyless, going-barrel, chronometer-watch, No. 147,625, with the " tourbillon " escapement, which obtained 88·0 marks out of a maximum of 100.

The best performance of *lever* watches during the year was that of No. 33,884 by Jos. White and Son, Coventry, which gained 84·9 marks.

Non-Magnetic Watches.—Twelve watches thus designated have been examined during the year, both as to their ordinary time-keeping and also as to their non-magnetic properties, and although the trial to which they are submitted is severe—the movement being tested in an intense magnetic field, both in vertical and horizontal positions, and gradually approached to and removed from the poles, whilst its behaviour is critically watched—in the majority of cases the watches were found to perform very satisfactorily.

Marine Chronometers.—The Committee having been requested by the Naval Attaché to the Royal Italian Embassy to undertake trials for Marine chronometers on the Greenwich plan, Mr. Constable visited the Royal Observatory, Greenwich, by kind permission of the Astronomer Royal, and was afforded every facility to make himself

familiar with the system of rating chronometers carried on there for many years past.

The Greenwich trial lasts for twenty-nine weeks, the movements being tried during alternate periods of seven and four weeks at the ordinary temperature of the air, and in a hot room at temperatures of from about 75° to 100° Fahr. This gives a total of twenty-one weeks at atmospheric temperatures and eight weeks in the oven.

The difference, in seconds, between the greatest and least weekly rates of a chronometer during the trial being denoted by a, and the greatest difference, in seconds, between the rates of two successive weeks by b, the smallness of the quantity $a + 2b$ has been adopted at Greenwich as the measure of the excellence of a chronometer.

At the request of the Italian Naval Attaché the test at Kew was to be directed to ascertain in which of the chronometers sent for trial the value of $a + 2b$ did not exceed 38.

It was decided to utilise for the trial the Pendulum Chamber in the basement and the North room in the new wing. The former is constructed of wood, double walled, with a 6-inch air space all round, and having been originally designed with a view to reducing temperature variations to a minimum, it was admirably suited for conversion into a hot chamber.

A gas furnace, made of copper to avoid the risk of disturbing the magnetographs, was specially built by Messrs. Fletcher, Russell, and Co., of Warrington. It has given entire satisfaction, being perfectly under control, so that any desired temperature up to 100° Fahr. can be reached and regularly maintained. By means of two copper flues the products of combustion are taken into the outer air, and the atmosphere of the hot chamber is at all times pure and free from fumes, while the presence of several open vessels of water prevents undue desiccation.

The North room referred to above is used for the ordinary temperature tests, and in it temperatures as low as 37° Fahr. have been observed. In addition to the ordinary maximum and minimum thermometers a "Richard" thermograph is used, which supplies a continual record of the temperature.

Two sets of trials were started during the year: the principal—for which 30 chronometers were entered—commencing on June 1, while the subsidiary—for which there were 12 entries—commenced on November 1. Of the 30 chronometers sent for the first trial only 14 attained the limit prescribed by the Italian Government. A brief summary of their performance will be found in Appendix III, Table III.

During the year 10 chronometers have been received for the ordinary trials. Of these 1 obtained the A certificate and 3 B certificates, while 2 failed to pass and 4 are still under examination.

A mean time Astronomical Regulator has also been rated at tem
peratures of 40° to 80° Fahr., and a statement of its performanc
issued.

VII. Miscellaneous.

Lens Testing.—During the year 31 lenses have been tested; of thes
13 received class A and 18 class B certificates. These number
though small show a gratifying increase on the two previous years.

The testing apparatus has been the subject of a good deal of ir
terest, several practical opticians of eminence and others intereste
in photography having inspected it and enquired into the details o
the various tests.

Library.—During the year the library has received as presents th
publications of—

26 Scientific Societies and Institutions of Great Britain an
  Ireland, and
108 Foreign and Colonial Scientific Establishments, as well as o
  numerous private individuals.

During the summer a partition was removed which used to divid
the library into an outer and an inner portion. The conversion into
single room has greatly improved the appearance of the library, an
has been found advantageous in various other ways.

Loans, &c., Repaid.—The Royal Society have been repaid half thei
loan of £400 made last year towards defraying the cost of the nev
building, and also the unspent balance—£117 1s. 7d.—of the per
dulum account.

Paper.—Prepared photographic paper has been procured and suj
plied to the Observatories at Aberdeen, Oxford, Stonyhurst, Lisbor
Mauritius, St. Petersburg, Toronto, and through the Meteorologica
Office to Batavia, Fort William and Valencia. Plain Papier Sax
has been sent to Coimbra Observatory, anemograph sheets to th
Hong-Kong and Mauritius Observatories, and blank forms for th
entry of magnetic observations to the Observatories at Falmouth an
Valencia, and to the Science and Art Department, London.

House, Grounds, and Path.—These have all been kept as usual durin
the year. In view of the increased and increasing extent to which th
Old Deer Park is now allotted to athletic clubs and other association
having for their object the public amusement, negotiations have bee
entered upon with the Office of Her Majesty's Woods and Forests fc
the purpose of securing ampler protection to the Observatory.

Subjoined to this Report will be found a list of instrument
apparatus, &c., the property of the Incorporated Kew Committee, a
present lent to various institutions and scientific men.

The balance sheet for the year, with a comparison of the expenditure for the two years 1892 and 1893 is also appended.   It is subject to a further audit by the Royal Society if the President and Council should so require.

PERSONAL ESTABLISHMENT.

The staff employed is as follows :—

C. Chree, M.A., Superintendent.
T. W. Baker, Chief Assistant.
E. G. Constable, Observations and Rating.
W. Hugo, Verification Department.
J. Foster   „   „
T. Gunter   „   „
W. J. Boxall   „   „
E. Dagwell, Observations and Rating.
R. S. Whipple, Accounts and Library, and five other Assistants.

FRANCIS GALTON,
Chairman.

April 11, 1894.

List of Instruments, Apparatus, &c., the Property of the Kew Committee, at the present date out of the custody of the Superintendent on Loan.

To whom lent.	Articles.	Date of loan
G. J. Symons, F.R.S.	Portable Transit Instrument	1869
The Science and Art Department, South Kensington.	Browning's Rigid Spectroscope, Photographic Self-Registering Horizontal Force Magnetometer, Photographic Self-Registering Declination Magnetometer, the St. Helena Magnetometers, Declination Compass used by Sir J. Richardson, Portable Vibration Apparatus used on H.M.S. "Thunderer" in 1841, Dip-Circle used by Sir J. Ross, Ronalds' Electrical Machine, Ronalds' Apparatus for Atmospheric Electricity, Thomson's Divided Ring Electrometer, Quadrant by Butterfield, Photographs of the Sun taken with the Kew Heliograph, Balance Anemometer by Ronalds, Ronalds' Rain and Vapour Gauge, Eight-haired Saussure's Hygrometer, Kreil's Barograph, Ronalds' Photo-Barometrograph, and a Model to show Galton's Method of Verifying Sextants	1876
Professor W. Grylls Adams, F.R.S.	Unifilar Magnetometer, by Jones, No. 101, complete	1888
	Pair 9-inch Dip-Needles with Bar Magnets . . .	1887
Captain W. de W. Abney, F.R.S.	Mason's Hygrometer, by Jones	1885
Lord Rayleigh, F.R.S.	Standard Barometer (Adie, No. 655)	1885
R. J. Ellery, F.R.S. .	Pendulum Apparatus, complete, with Richard Thermograph.	1892

Kew Observatory.　Account of Receipts and Payments for the year ending December 31st, 1893.

Dr.　RECEIPTS.

	£ s. d.	£ s. d.
To Balance from Year 1892		529 2 9
Royal Society:—		
(Gassiot Trust)		486 9 2
Meteorological Council:—		
Allowance.........	400 0 0	
Postages, &c.	7 18 5	
		407 18 5
Researches.........		6 16 2
Tests:—		
Verifications	1131 1 8	
Rating	718 1 10	
Lenses.........	15 19 9	
		1865 3 3
Gravity Survey Committee for Pendulums		5 10 0
Commissions executed for Colonial and Foreign Institutions, &c......		183 19 6
		£2484 19 3

PAYMENTS.　Cr.

	£ s. d.	£ s. d.
By Administration:—		
Superintendent	291 13 4	
Salaries, Wages, &c.	148 18 0	
Rent, Fuel, and Lighting......	85 12 8	
Attendance, Cleaning, Repairs,* and Insurance	278 19 10	
Donation to "Whipple "Fund	50 0 0	
		855 3 5
Normal Observatory:—		
Salaries—Observations, Tabulations, &c.	340 18 5	
Incidental Expenses, Instruments, &c.	63 17 5	
		404 15 10
Researches:—		
Salaries—Observations, Reductions, &c.		227 4 0
Tests:—		
Salaries.........	866 18 0	
Incidental Expenses—Instruments, Postages, &c. ...	181 8 7	
		1048 6 7
Commissions for Colonial and Foreign Institutions, &c.		146 2 7
Royal Society:—		
Partial repayment of Loan for Extension of Premises......	200 0 0	
Payment of Balance of Pendulum Account	117 1 7	
		317 1 7
Balance :—		
Cash at Bank of England	357 16 2	
„ London and County Bank, Richmond......	112 10 0	
„ Observatory (for Banking)	8 10 0	
„ „ (Petty Cash)	7 9 1	
		486 5 3
		£2484 19 3

January 31, 1894.

Examined and compared with the vouchers, and found correct.

(Signed)　BOSSE, *Auditor.*

* This includes "Extension of Premises."

ESTIMATED ASSETS.

	£	s.	d
By Balance as per Statement	486	5	3
Payments due:—			
Meteorological Council—Allowance, Postages, &c. (£106 9 3)			
Test Fees (491 16 11)			
Commissions (102 17 9)	704	3	11
Stock:—			
Blank Forms and Certificates (48 16 10)			
Standard Thermometers (83 19 0)	132	15	10
	£1323	5	0

ESTIMATED LIABILITIES.

	£	s.	d.
To Administration accounts—Gas, Repairs, and Contingencies	38	4	8
Observatory accounts—A.G.B. Paper, Chemicals, &c.	8	3	3
Tests accounts—Fittings, Printing, &c.	29	6	1
Royal Society (Balance of Loan)	200	0	0
Commissions	98	17	10
General Balance	963	13	2
	£1323	5	0

February 2, 1894.

(Signed)   CHARLES CHREE,
Superintendent.

Comparison of Expenditure (excluding Commissions) for the twelve months ending December 31st, 1892, and December 31st, 1893.

Heads of Expenditure.	1892.			1893.			Increase.			Decrease.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Administration—												
Superintendent......	400	0	0	291	13	4	..			108	6	8
Office...............	200	3	0	148	18	0	..			51	5	0
Rent, fuel, lighting, &c. ...:............	58	15	10	85	12	3	26	16	5			
Attendance and contingencies	184	12	10	219	3	1	34	10	3			
"Whipple" Fund ..	..			50	0	0	50	0	0			
Normal Observatory—												
Salaries	296	12	0	340	18	5	44	6	5			
Incidental expenses..	31	14	11	63	17	5	32	2	6			
Researches—												
Salaries	223	5	0	227	4	0	3	19	0			
Incidental expenses..	2	11	0	..			..			2	11	0
Tests—												
Salaries	858	17	7	866	18	0	8	0	5			
Incidental expenses..	183	15	2	181	8	7	..			2	6	7
Ordinary expenditure, showing an increase of £35 5s. 9d.	2,440	7	4	2,475	13	1	199	15	0	164	9	3
Repayment of Loan from Royal Society ..	..			200	0	0	200	0	0			
Payment of unexpended balance of Pendulum Grant....	..			117	1	7	117	1	7			
Extension of Premises..	656	10	0	59	16	9	..			596	13	3
							516	16	7	761	2	6
Total expenditure......	3,096	17	4	2,852	11	5	..			244	5	11

APPENDIX A.

MEMORANDUM OF ASSOCIATION.

1. The name of the Association is "THE INCORPORATED KEW COMMITTEE OF THE ROYAL SOCIETY."

2. The registered office of the Association will be situate in England.

3. The objects for which the Association is established are:—

    1. The administration, under the direction of the Royal Society, of so much as shall be paid to them of the income of the Trust Fund founded by Mr. GASSIOT for maintaining the Kew Observatory and carrying on the magnetic, meteorological, and other physical observations there, but the Royal Society is not to be responsible for the acts or omissions of the Association, or for the Application of the income of the said Trust Fund when paid over to the Association, or for the misapplying of such income or for any debts or liabilities which may be incurred by the Association.

    2. The maintenance and the management of an Institution for the supply, examination, and testing of instruments for scientific and other purposes, and the investigation and application of methods of measurement and observation.

    3. The doing all such lawful things as are incidental or conducive to the attainment of the above objects.

4. The income and property of the Association, whencesoever derived, shall be applied solely towards the promotion of the objects of the Association as set forth in this Memorandum of Association; and no portion thereof shall be paid or transferred directly or indirectly, by way of dividend, bonus, or otherwise howsoever by way of profit, to the Members of the Association.

Provided that nothing herein shall prevent the payment, in good faith, of remuneration to any officers or servants of the Association, or to any Member of the Association, or other person, in return for any services actually rendered to the Association.

5. The fourth paragraph of this Memorandum is a condition on which a licence is granted by the Board of Trade to the Association in pursuance of Section 23 of the Companies Act, 1867.

6. If any Member of the Association pays or receives any dividend, bonus, or other profit, in contravention of the terms of the fourth paragraph of this Memorandum, his liability shall be unlimited.

7. Every Member of the Association undertakes to contribute to the assets of the Association, in the event of the same being wound up during the time that he is a Member, or within one year afterwards, for payment of the debts and liabilities of the Association contracted before the time at which he ceases to be a Member, and of the costs, charges, and expenses of winding up the same, and for the adjustment of the rights of the contributories amongst themselves, such amount as may be required not exceeding one pound, or in case of his liability becoming unlimited, such other amount as may be required in pursuance of the last-preceding paragraph of this Memorandum.

8. If upon the winding up or dissolution of the Association there remains, after the satisfaction of all its debts and liabilities, any property whatsoever, the same shall not be paid to or distributed among the Members of the Association, but shall be given or transferred to the President and Council of the Royal Society, and on any winding up the Association shall consent to the appointment of any liquidator who may be nominated by the said President and Council.

9. True accounts shall be kept of the sums of money received and expended by the Association and the matter in respect of which such receipt and expenditure takes place, and of the properties, credits, and liabilities of the Association ; and, subject to any reasonable restrictions as to the time and manner of inspecting the same that may be imposed in accordance with the Regulations of the Association for the time being, shall be open to inspection of the Members and to the President and Council of the Royal Society. The accounts of the Association shall be submitted annually to the Royal Society for audit, or to any auditor or auditors to be appointed from time to time by the Royal Society, or by the Association acting under the authority of the Royal Society.

We, the several persons whose names and addresses are subscribed, are desirous of being formed into an Association in pursuance of this Memorandum of Association.

Signed by Members of the Committee.

Dated the 31st day of January, 1893.

ARTICLES OF ASSOCIATION.

(1.) For the purposes of registration the number of the Members of the Association is declared not to exceed twelve.

(2.) These Articles shall be construed with reference to the provisions of the Companies Act, 1862, and the Companies Act, 1867, and terms used in these Articles shall be taken as having the same respective meanings as they have when used in those Acts.

(3.) The Association is established for the purposes and subject to the conditions expressed in the Memorandum of Association.

(4.) *Qualification of Members.*—The Association shall consist of such of the present Members of the Kew Committee of the Royal Society as consent to be Members.

(5.) *Admission of Members.*—Future Members shall be nominated from time to time by the Council, for the time being, of the Royal Society.

(6.) *Honorary Officers and their Elections.*—The Chairman shall be nominated by the Council of the Royal Society.

(7.) *Management of the Association.*—The business is to be managed by the Members of the Association.

(8.) *Meetings, Proceedings, &c.*—The First General Meeting of the Association shall be held within four months after the registration of the Memorandum of Association. A General Meeting shall be held at least once in each year, in accordance with Section 49 of the Companies Act of 1862. The Ordinary Meetings of the Association shall be held as the Committee shall direct, and their proceedings shall be regularly recorded. The Association shall submit yearly a Report of its proceedings to the Royal Society.

(9.) *Accounts, Audit.*—The annual statement of income and expenditure of the Association shall be sent to the President and Council of the Royal Society for audit, as provided by Section 9 of the Memorandum of Association.

(10.) A notice may be served by the Association upon any Member, either personally or by sending it through the post as a prepaid letter, addressed to such Member at his registered place of abode.

Any notice, if served by post, shall be deemed to have been served at the time when the letter containing the same would be delivered in the ordinary course of the post, and in proving such service it shall be sufficient to prove that the letter containing the notice was properly addressed and put into the Post Office.

Signed by Members of the Committee.

Dated the 31st day of January, 1893.

APPENDIX I.

MAGNETICAL OBSERVATIONS, 1893.

Made at the Kew Observatory, Richmond, Lat. 51° 28′ 6″ N. and Long. $0^h 1^m 15^s \cdot 1$ W., height 34 feet above mean sea-level.

The results given in the following tables are deduced from the magnetograph curves which have been standardised by observations of deflection and vibration. These were made with the Collimator Magnet K.C. I. and the Declinometer Magnet marked K.O. 90 in the 9-inch Unifilar Magnetometer by Jones.

The Inclination was observed with the Inclinometer by Barrow, No. 33, and needles 1 and 2, which are $3\frac{1}{2}$ inches in length.

The Declination and Force values given in Tables I to VIII are prepared in accordance with the suggestions made in the fifth report of the Committee of the British Association on comparing and reducing Magnetic Observations.

The following is a list of the days during the year 1893 which were selected by the Astronomer Royal, as suitable for the determination of the magnetic diurnal variations, and which have been employed in the preparation of the magnetic tables :—

January	7, 8, 15, 25, 26.
February	1, 11, 13, 26, 27.
March	10, 13, 18, 19, 20.
April..............	4, 9, 21, 22, 23.
May	2, 14, 17, 21, 28.
June	8, 13, 17, 22, 24.
July	5, 6, 10, 30, 31.
August............	1, 9, 16, 17, 27.
September	4, 7, 13, 23, 24.
October............	9, 11, 16, 21, 22.
November..........	7, 11, 15, 20, 21.
December..........	7, 13, 18, 21, 22.

z 2

Table I.—Hourly Means of Declination, as

Hours	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
(17° +) West.						Winter.						
1893. **Months.**	′	′	′	′	′	′	′	′	′	′	′	′
Jan. ..	28·9	29·6	30·4	31·2	31·6	31·6	31·8	81·6	31·3	31·3	32·3	34·0
Feb. ..	31·3	31·2	31·1	31·2	31·0	30·8	30·5	29·9	29·4	29·8	31·6	34·1
March .	30·3	30·2	29·7	29·6	29·2	28·9	28·4	27·7	26·3	26·6	28·5	32·2
Oct. ..	25·1	25·1	25·0	25·1	25·1	25·1	24·4	23·7	22·9	22·7	24·4	27·8
Nov. ..	23·7	24·3	24·4	24·4	24·3	24·3	24·0	23·5	22·8	22·4	23·8	26·8
Dec. ..	25·2	25·6	26·1	26·1	25·9	25·6	25·6	25·3	25·2	24·5	25·2	26·4
Mean .	27·4	27·7	27·8	27·9	27·8	27·7	27·4	26·9	26·3	26·2	27·6	30·2
Summer.												
	′	′	′	′	′	′	′	′	′	′	′	′
April..	30·4	30·3	30·3	30·1	29·9	29·5	28·1	27·0	25·4	25·7	27·5	31·9
May ..	28·7	29·0	29·1	28·6	28·0	26·1	24·9	23·7	23·4	24·7	27·9	32·3
June ..	29·4	28·7	28·6	28·3	27·4	25·5	23·9	23·8	23·6	24·8	27·6	30·7
July ..	26·2	26·1	25·8	25·6	24·9	23·5	22·1	21·2	21·4	22·9	25·8	29·6
Aug. ..	27·6	27·6	27·2	26·9	26·2	25·2	23·4	22·2	22·8	24·4	27·0	30·3
Sept...	26·0	25·9	26·1	25·2	24·6	24·6	23·7	23·0	22·2	23·8	26·8	30·6
Mean.	28·0	27·9	27·8	27·4	26·8	25·7	24·3	23·5	23·1	24·4	27·1	30·9

Table II.—Solar Diurnal Range of the Kew

Hours	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Summer mean.												
	′	′	′	′	′	′	′	′	′	′	′	′
	−0·8	−0·9	−1·0	−1·4	−2·0	−3·1	−4·5	−5·3	−5·7	−4·4	−1·7	+2·1
Winter mean.												
	′	′	′	′	′	′	′	′	′	′	′	′
	−1·5	−1·2	−1·1	−1·0	−1·1	−1·2	−1·5	−2·0	−2·6	−2·7	−1·3	+1·3
Annual mean.												
	′	′	′	′	′	′	′	′	′	′	′	′
	−1·1	−1·0	−1·0	−1·2	−1·5	−2·1	−3·0	−3·6	−4·1	−3·5	−1·5	+1·7

Note.—When the sign is + the magnet

determined from the selected quiet Days in 1893.

Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
						Winter.						
35·6	36·4	36·2	35·3	35·1	34·5	33·8	33·3	32·8	32·0	31·8	31·4	31·4
35·9	36·3	35·9	35·0	33·7	32·9	32·5	32·1	32·0	31·6	31·3	31·1	31·2
36·2	38·4	38·4	36·3	34·2	31·9	31·6	30·9	30·5	30·3	30·5	30·4	30·1
30·5	31·8	31·6	30·1	28·6	27·6	27·0	26·5	25·9	25·1	25·1	24·9	24·7
29·0	29·9	29·1	28·2	27·4	26·7	26·2	26·0	25·0	24·7	24·5	24·5	24·8
27·8	28·7	28·9	28·5	27·7	27·1	26·9	26·4	25·7	25·6	25·4	25·4	25·1
32·5	33·6	33·3	32·2	31·1	30·1	29·7	29·2	28·6	28·2	28·1	27·9	27·9
						Summer.						
35·9	38·7	38·5	36·8	34·6	32·4	31·1	31·1	31·0	31·0	30·8	30·6	30·4
36·5	37·9	37·0	35·3	32·7	30·9	29·7	29·4	29·5	29·6	29·4	29·1	29·2
34·0	35·8	36·0	34·4	32·9	31·4	30·4	29·5	29·4	29·2	29·5	29·1	29·2
32·3	33·9	34·4	33·3	31·0	28·8	27·5	26·6	26·5	26·8	27·2	27·1	26·6
33·9	35·6	35·2	33·5	31·3	29·1	28·2	28·2	27·7	27·7	27·6	27·6	27·6
33·9	34·7	34·5	32·6	30·3	28·5	27·7	27·5	27·1	26·9	26·7	25·8	25·6
34·4	36·1	35·9	34·3	32·1	30·2	29·1	28·7	28·5	28·5	28·5	28·2	28·1

Declination as derived from Table I.

Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
						Summer mean.						
+5·6	+7·3	+7·1	+5·5	+3·3	+1·4	+0·3	−0·1	−0·3	−0·3	−0·3	−0·6	−0·7
						Winter mean.						
+3·6	+4·7	+4·4	+3·3	+2·2	+1·2	+0·8	+0·3	−0·3	−0·7	−0·8	−1·0	−1·0
						Annual mean.						
+4·6	+6·0	+5·7	+4·4	+2·7	+1·3	+0·5	+0·1	−0·3	−0·5	−0·5	−0·8	−0·9

points to the west of its mean position.

Table III.—Hourly Means of the Horizontal Force in C.G.S. units

Hours	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
0·18000 + Winter.												
1893. Months.												
Jan. ..	208	210	210	214	217	219	219	221	218	213	207	201
Feb. ..	235	235	234	235	236	236	236	235	231	219	213	210
March .	230	228	228	227	227	227	227	225	217	203	196	194
Oct. ..	246	243	241	245	243	245	243	239	229	219	210	211
Nov. ..	236	237	238	236	239	239	239	238	234	222	211	209
Dec. ..	251	251	252	253	254	257	259	259	257	252	245	240
Mean.	234	234	234	235	236	237	237	236	231	221	214	211
Summer.												
April ..	246	245	245	245	246	247	250	249	241	227	209	199
May ..	244	244	244	246	245	242	238	231	218	208	205	209
June ..	247	243	242	243	243	241	236	228	221	214	212	212
July ..	255	254	252	253	253	253	248	239	230	222	218	220
Aug. ..	260	261	261	261	261	259	252	243	235	225	220	224
Sept. ..	250	249	250	247	248	245	241	236	226	219	212	216
Mean ..	250	249	249	249	249	248	244	238	228	219	213	213

Table IV.—Diurnal Range of the Kew

Hours.	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Summer mean.												
	+ ·00006	+ ·00005	+ ·00006	+ ·00006	+ ·00005	+ ·00004	·00000	− ·00006	− ·00016	− ·00025	− ·00031	− ·00031
Winter mean.												
	+ ·00002	+ ·00002	+ ·00002	+ ·00003	+ ·00004	+ ·00005	+ ·00005	+ ·00004	− ·00001	− ·00011	− ·00018	− ·00021
Annual mean.												
	+ ·00004	+ ·00003	+ ·00003	+ ·00004	+ ·00004	+ ·00004	+ ·00002	− ·00001	− ·00006	− ·00018	− ·00024	− ·00026

Note.—When the sign is + the

(corrected for Temperature), as determined from the selected quiet Days in 189?

Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
					Winter.							
207	213	213	212	212	213	218	220	218	217	218	219	221
216	223	230	229	230	231	235	236	239	238	237	238	238
199	207	218	228	229	228	231	233	235	234	233	232	230
219	225	229	233	237	239	245	245	245	250	248	249	248
211	217	223	229	233	238	240	240	240	241	241	240	241
241	245	248	251	254	256	257	259	257	258	257	255	252
216	222	227	229	232	234	238	239	239	240	239	239	238
					Summer.							
201	213	225	237	243	247	248	249	253	250	250	248	248
221	229	239	247	253	256	255	255	255	255	251	251	252
220	226	237	244	251	256	257	260	257	255	254	252	252
230	235	243	255	259	264	270	269	266	264	260	258	256
234	245	253	258	262	263	264	267	267	269	265	264	263
225	234	243	247	245	249	254	255	258	259	259	259	255
222	230	240	248	252	256	258	259	259	259	256	255	254

Horizontal Force as deduced from Table III.

Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
					Summer mean.							
− ·00022	− ·00014	− ·00004	+ ·00004	+ ·00008	+ ·00012	+ ·00014	+ ·00015	+ ·00015	+ ·00015	+ ·00012	+ ·00011	+ ·000
					Winter mean.							
− ·00016	− ·00010	− ·00005	− ·00003	·00000	+ ·00002	+ ·00006	+ ·00007	+ ·00007	+ ·00008	+ ·00007	+ ·00007	+ ·000
					Annual mean.							
− ·00019	− ·00012	− ·00004	·00000	+ ·00004	+ ·00007	+ ·00010	+ ·00011	+ ·00011	+ ·00011	+ ·00009	+ ·00009	+ ·000

reading is above the mean.

Table V.—Hourly Means of the Vertical Force in C.G.S. units (corrected

Hours	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
0·48000 +						Winter.						
1893. Months.												
Jan. ..	942	939	939	938	938	938	938	939	939	940	937	934
Feb. ..	956	956	955	955	955	955	955	955	956	955	951	950
March .	902	902	902	903	904	906	906	909	909	905	900	893
Oct. ..	854	854	854	853	853	852	852	853	852	850	844	840
Nov. ..	901	901	899	900	900	900	900	900	901	899	895	894
Dec. ..	923	923	923	922	922	922	921	922	921	920	917	916
Mean ..	913	913	912	912	912	912	912	913	913	912	907	905
						Summer.						
April..	905	907	907	908	910	911	912	913	912	909	900	891
May ..	870	871	872	871	871	874	875	875	871	863	852	842
June ..	841	841	842	843	845	849	850	848	844	838	831	825
July ..	866	867	869	871	874	877	877	876	872	867	862	855
Aug. ..	924	925	925	926	927	929	930	930	925	919	912	908
Sept. ..	901	902	903	903	904	905	906	907	905	900	891	888
Mean..	885	886	886	887	889	891	892	892	888	883	875	868

Table VI.—Diurnal Range of the Kew

Hours.	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
						Summer mean.						
	+ ·00002	+ ·00003	+ ·00003	+ ·00004	+ ·00006	+ ·00008	+ ·00009	+ ·00009	+ ·00005	·00000	− ·00008	− ·00015
						Winter mean.						
	+ ·00003	+ ·00003	+ ·00002	+ ·00002	+ ·00002	+ ·00002	+ ·00002	+ ·00003	+ ·00003	+ ·00002	− ·00003	− ·00005
						Annual mean.						
	+ ·00003	+ ·00003	+ ·00003	+ ·00003	+ ·00004	+ ·00005	+ ·00006	+ ·00006	+ ·00004	+ ·00001	− ·00006	− ·00010

NOTE.—When the sign is + the

for Temperature), as determined from the selected quiet Days in 1893.

Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
					Winter.							
932	936	939	942	943	944	943	944	943	941	940	939	939
949	948	950	952	955	955	955	954	953	954	955	956	955
889	891	896	902	907	907	907	905	904	903	903	904	902
840	842	843	848	850	850	849	848	848	848	848	848	848
894	897	898	901	900	900	897	897	897	896	896	895	894
916	917	919	923	923	922	920	920	919	918	918	918	918
903	905	908	911	913	913	912	911	911	910	910	910	909
					Summer.							
887	885	892	899	904	911	911	911	910	909	908	909	909
842	846	855	863	868	871	871	868	867	865	864	863	863
825	830	832	835	837	840	841	841	838	837	834	835	834
851	851	856	865	872	878	880	878	876	874	872	870	868
907	909	917	920	922	926	922	920	918	916	916	916	916
889	890	895	901	904	906	906	906	905	904	905	906	906
867	869	875	881	885	889	889	887	886	884	883	883	883

Vertical Force as deduced from Table V.

Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
					Summer mean.							
− ·00016	− ·00014	− ·00008	− ·00002	+ ·00002	+ ·00006	+ ·00006	+ ·00004	+ ·00003	+ ·00001	·00000	·00000	·0000
					Winter mean.							
− ·00007	− ·00005	− ·00002	+ ·00001	+ ·00003	+ ·00003	+ ·00002	+ ·00001	+ ·00001	·00000	·00000	·00000	− ·000
					Annual mean.							
− ·00012	− ·00010	− ·00005	·00000	+ ·00003	+ ·00005	+ ·00004	+ ·00003	+ ·00002	+ ·00001	·00000	·00000	·0000

reading is above the mean.

Table VII.—Hourly Means of the Inclination, calculated

Hours .	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
67° +						Winter.						
1893. Months.	′	′	′	′	′	′	′	′	′	′	′	′
Jan....	29·6	29·3	29·3	29·1	28·8	28·7	28·7	28·6	28·8	29·2	29·5	29·8
Feb....	28·2	28·2	28·2	28·1	28·1	28·1	28·1	28·1	28·4	29·2	29·5	29·7
March.	27·0	27·1	27·1	27·2	27·2	27·3	27·3	27·5	28·0	28·9	29·2	29·1
Oct....	24·6	24·8	24·9	24·6	24·8	24·6	24·7	25·0	25·7	26·3	26·7	26·5
Nov. ..	26·5	26·5	26·4	26·5	26·3	26·3	26·3	26·4	26·7	27·4	28·1	28·2
Dec....	26·2	26·2	26·1	26·0	25·9	25·7	25·6	25·6	25·7	26·0	26·4	26·7
Mean .	27·0	27·0	27·0	26·9	26·9	26·8	26·8	26·9	27·2	27·8	28·2	28·3
						Summer.						
	′	′	′	′	′	′	′	′	′	′	′	′
April ..	26·0	26·1	26·1	26·1	26·1	26·1	25·9	26·0	26·5	27·4	28·3	28·7
May...	25·2	25·2	25·2	25·1	25·1	25·4	25·7	26·2	26·9	27·4	27·3	26·7
June ..	24·2	24·4	24·5	24·5	24·5	24·8	25·1	25·6	26·0	26·3	26·2	26·0
July...	24·3	24·4	24·6	24·6	24·7	24·8	25·1	25·7	26·1	26·5	26·7	26·3
Aug. ..	25·6	25·6	25·6	25·6	25·6	25·8	26·3	26·9	27·3	27·8	27·9	27·6
Sept. ..	25·6	25·7	25·7	25·9	25·8	26·1	26·4	26·7	27·3	27·7	27·9	27·5
Mean.	25·2	25·2	25·3	25·3	25·3	25·5	25·8	26·2	26·7	27·2	27·4	27·1

Table VIII.—Diurnal Range of the

Hours	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
						Summer mean.						
	′	′	′	′	′	′	′	′	′	′	′	′
	−0·3	−0·3	−0·2	−0·2	−0·2	0·0	+0·3	+0·7	+1·2	+1·7	+1·9	+1·6
						Winter mean.						
	′	′	′	′	′	′	′	′	′	′	′	′
	−0·1	−0·1	−0·1	−0·2	−0·2	−0·3	−0·3	−0·2	+0·1	+0·7	+1·1	+1·2
						Annual mean.						
	′	′	′	′	′	′	′	′	′	′	′	′
	−0·2	−0·2	−0·2	−0·2	−0·2	−0·2	0·0	+0·3	+0·7	+1·2	+1·5	+1·4

NOTE.—When the sign is +

from the Horizontal and Vertical Forces (Tables III and V).

Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
Winter.												
29·4	29·1	29·1	29·3	29·3	29·3	28·9	28·8	28·9	28·9	28·8	28·7	28·6
29·2	28·7	28·3	28·4	28·5	28·4	28·1	28·0	27·8	27·9	28·0	28·0	27·9
28·7	28·2	27·6	27·5	27·2	27·3	27·1	26·9	26·7	26·7	26·8	26·9	27·0
26·0	25·6	25·4	25·3	25·1	24·9	24·5	24·5	24·5	24·2	24·3	24·2	24·3
28·0	27·7	27·3	27·0	26·7	26·4	26·2	26·2	26·2	26·1	26·1	26·1	26·0
26·6	26·4	26·3	26·2	26·0	25·8	25·7	25·5	25·7	25·6	25·6	25·8	26·0
28·0	27·6	27·3	27·3	27·1	27·0	26·8	26·7	26·6	26·6	26·6	26·6	26·6
Summer.												
28·5	27·6	27·0	26·4	26·2	26·1	26·0	26·0	25·7	25·8	25·8	26·0	26·0
25·9	25·5	25·1	24·8	24·5	24·4	24·5	24·4	24·3	24·3	24·5	24·5	24·4
25·5	25·3	24·6	24·2	23·8	23·5	23·5	23·8	23·4	23·5	23·5	23·7	23·6
25·6	25·2	24·8	24·3	24·2	24·0	23·7	23·7	23·9	23·9	24·1	24·2	24·3
26·9	26·2	25·9	25·6	25·4	25·4	25·3	25·0	25·0	24·8	25·0	25·1	25·2
27·0	26·4	25·9	25·8	26·0	25·8	25·5	25·4	25·2	25·1	25·1	25·2	25·5
26·6	26·0	25·6	25·2	25·0	24·9	24·8	24·6	24·6	24·6	24·7	24·8	24·8

Inclination as deduced from Table VII.

Noon.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
Summer mean.												
+1·1	+0·5	+0·1	−0·3	−0·5	−0·6	−0·7	−0·9	−0·9	−0·9	−0·8	−0·7	−0·7
Winter mean.												
+0·9	+0·5	+0·2	+0·2	0·0	−0·1	−0·3	−0·4	−0·5	−0·5	−0·5	−0·5	−0·5
Annual mean.												
+1·0	+0·5	+0·2	−0·1	−0·3	−0·4	−0·5	−0·7	−0·7	−0·7	−0·7	−0·6	−0·6

the reading is above the mean.

APPENDIX II.—Table I.

Mean Monthly Results of Temperature and Pressure.
Kew Observatory.

Months. 1898.	Thermometer. Mean.	Means of — Max.	Means of — Min.	Means of — Max. and Min.	Absolute Extremes. Max.	Date. d. h.	Min.	Date. d. h.	Barometer.* Mean. ins.	Max. ins.	Date. d. h.	Min. ins.	Date. d. h.	Mean vapour-tension. in.
Jan....	35·8	39·6	31·9	35·8	52·2	31 1 P.M.	13·1	5 5 A.M.	30·069	30·455	19 9 A.M.	29·441	29 1 P.M.	·184
Feb....	41·7	46·8	36·7	41·8	56·3	19 2&8 "	23·0	6 8 "	29·728	30·441	5 11 "	28·689	21 2 "	·223
March..	45·4	55·2	36·8	45·8	64·9	29 3 "	26·9	19 6 "	30·145	30·487	19 8 "	29·583	1 2 "	·224
April..	50·8	62·4	40·9	51·7	80·3	20 3 "	30·8	14 5 "	30·163	30·529	8 9 "	29·887	19 8 "	·244
May....	56·7	66·8	47·2	57·0	76·2	15 11 A.M.	39·9	31 4 "	30·062	30·432	6 6 "	29·497	17 5 "	·310
June...	61·1	71·1	51·1	61·1	86·1	19 4 P.M.	38·9	1 4 "	30·012	30·416	6 10 "	29·383	23 9 A.M.	·345
July...	63·3	72·0	55·5	63·8	85·6	7 4 "	48·1	15 1 "	29·907	30·306	28 8 "	29·540	12 6 P.M.	·403
Aug....	65·0	74·4	56·1	65·3	88·6	17 4 "	43·6	29 5 "	30·037	30·341	29 2 "	29·627	21 10 A.M.	·424
Sept...	56·8	65·3	49·0	57·2	77·2	6 3 "	38·7	24 5 "	29·879	30·322	12 9 "	29·279	30 5 "	·340
Oct....	51·4	57·8	44·9	51·4	65·3	16 3 "	30·3	31 + ?	29·919	30·489	23 10 P.M.	29·185	4 2 P.M.	·304
Nov....	42·2	47·1	36·9	42·0	59·6	3 2 "	28·9	1 6 "	29·997	30·465	21 10 "	29·002	17 5 "	·228
Dec....	40·2	45·3	33·7	39·5	55·8	13 1 "	20·8	8 6 "	30·019	30·778	30 2 A.M.	28·567	20 5 "	·218
Yearly Means	50·9	58·7	43·4	51·0	..	....	..	....	29·995	..	....	..	....	·287

* Reduced to 32° at M.S.L.
† From ordinary Min. Ther.; the thermograph trace was lost through stoppage of the clock.

This Table is compiled from "Hourly Means," vol. 1893, of the Meteorological Office.

Meteorological Observations.—Table II.

Kew Observatory.

Months.	Mean amount of cloud (0=clear, 10=over-cast).	Rainfall.*			Weather. Number of days on which were registered							Wind.† Number of days on which it was								
		Total.	Maxi-mum.	Date.	Rain.†	Snow.	Hail.	Thun-der-storms.	Clear sky.	Over-cast sky.	Gale.	N.	N.E	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
1898.		in.	in.																	
January......	7·5	1·430	0·295	9	25	6	..	..	8	19	..	6	3	2	2	3	..	7	3	5
February.....	7·1	2·660	0·465	27	23	2	1	..	4	15	3	5	2	..	3	6	5	6	1	2
March.......	3·9	0·230	0·045	8	6	2	..	..	18	9	..	2	3	7	1	4	9	5	2	9
April........	2·6	0·100	0·060	20	8	..	..	..	20	1	..	4	8	11	1	2	8	1	1	1
May.........	5·4	1·395	0·765	17	10	..	..	1	9	9	..	4	6	6	..	5	3	2	4	2
June	5·1	0·880	0·245	{22 {27	11	..	..	1	11	11	1	2	6	8	2	2	4	5	1	3
July.........	6·5	1·815	0·360	17	17	..	..	4	2	13	..	5	2	4	..	6	6	5	3	4
August	5·4	1·705	0·760	4	12	..	..	3	6	4	..	2	3	3	1	3	11	4	4	5
September....	5·7	0·995	0·175	{20 {26	9	..	..	2	8	9	..	2	4	8	..	1	6	10	4	6
October	6·7	4·115	1·205	9	14	..	..	1	5	11	..	4	1	2	..	2	12	9	1	3
November....	7·6	1·975	0·700	14	15	2	2	..	6	20	1	8	6	2	1	1	5	5	2	2
December	6·1	2·220	0·425	8	18	1	1	..	8	10	4	3	..	..	1	6	13	6	2	3
Totals and means......	5·8	19·500			162	13	4	11	99	131	9	44	43	48	12	41	85	64	28	56

* Measured at 10 A.M. daily by gauge 1·75 feet above ground.   † As registered by the anemograph.

‡ The number of rainy days are those on which 0·01 inch rain or melted snow was recorded.

Note.—For total rainfall, February, 1892, 0·405, read 1·405.

Meteorological Observations.—Table III.
Kew Observatory.

Months.	Bright Sunshine.				Maximum temperature in sun's rays. (Black bulb *in vacuo*.)			Minimum temperature on the ground.			Horizontal movement of the air.[*]		
	Total number of hours recorded.	Mean percentage of possible sunshine.	Greatest daily record.	Date	Mean.	Highest.	Date.[†]	Mean.	Lowest.	Date.[‡]	Average hourly velocity.	Greatest hourly velocity.	Date.
1898.	h. m.		h. m.		deg.	deg.		deg.	deg.		miles.	miles.	
January	22 24	9	5 0	15	56	82	28	26	7	5	9·8	27	29
February	63 18	23	7 6	28	77	99	19	31	17	6	13·3	42	10
March	157 12	42	10 36	31	100	118	31	28	16	19	8·9	33	1
April	243 48	59	12 24	26	109	134	20	32	19	14	11·0	33	22
May	205 24	43	13 42	10	120	130	29	39	28	11	9·9	30	5
June	206 24	42	14 12	18	124	139	19	43	29	1	9·6	35	28
July	174 48	35	13 30	7	126	138	21	50	39	23	9·9	31	9
August	225 18	50	12 42	16	126	138	11	48	32	29	9·2	33	22
September	151 54	40	9 36	{12 / 24}	115	133	14	42	29	24	8·9	30	29
October	133 54	41	9 30	3	100	116	1	37	18	31	8·2	29	25
November	42 54	16	6 12	7	69	96	3	31	18	1 & 13	13·2	38	18
December	54 12	22	6 6	2	67	81	24	27	12	3	10·9	49	12
Totals and Means	1681 30	35	..	..	99	..	..	36	..	..	10·2	..	..

[*] As indicated by a Robinson's anemograph, 70 feet above the general surface of the ground.
[†] Read at 10 A.M., and entered to previous day.   [‡] Read at 10 A.M., and entered to same day.

Table IV.

Summary of Sun-spot Observations made at the Kew Observatory.

Months.	Days of observation.	Number of new groups enumerated.	Days apparently without spots.
1893.			
January	8	14	—
February...............	10	11	—
March.................	12	15	—
April..................	20	18	—
May...................	15	17	—
June	17	19	—
July...................	12	10	—
August	18	20	—
September..............	11	12	—
October................	15	15	—
November..............	8	13	—
December	9	9	—
Totals for 1893	155	173	—

APPENDIX III.—Table I.

RESULTS OF WATCH TRIALS. Performance of the 34 Watches which obtained the highest number of marks during the year.

Watch deposited by	Number of watch	Balance spring, escapement, &c.	Mean daily rate — Pendant up	Pendant right	Pendant left	Dial up	Dial down	Mean variation of daily rate, ±	Mean change of rate for 1 y.	Difference between extreme gaining and losing rates	Marks awarded for — Daily variation of rate	Change of rate with change of position	Temperature compensation	Total Marks 0—100
Stauffer, Son, & Co., London	147625	Single overcoil, g.b., "tourbillon" chronometer	+2·2	+1·6	+2·4	−0·8	+1·8	0·8	0·04	6·2	34·0	36·0	17·4	88·0
L. Borst, Chaux-de-Fonds	2324	Single overcoil, g.b., "tourbillon" chronometer	+1·4	+1·2	+1·5	+2·0	+2·4	0·4	0·06	5·4	52·2	38·4	15·0	85·6
J. White & Son, Coventry	33884	Single overcoil, s.r., g.b. centre seconds, lever	+1·4	+0·4	+1·0	+0·5	+3·1	0·5	0·04	6·5	30·5	30·9	17·5	84·9
A. E. Fridlander, Coventry	13834	Single overcoil, s.r., g.b.	−1·6	−3·2	−1·0	−3·7	+3·0	0·4	0·03	7·2	32·5	33·2	18·2	84·0
J. White & Son, Coventry	34044	Single overcoil, s.r., g.b., centre seconds	−0·5	−0·7	+0·1	+1·2	+1·2	0·4	0·06	6·3	31·2	36·7	16·1	84·0
A. E. Fridlander, Coventry	13847	Single overcoil, s.r., g.b. centre seconds	−2·3	−2·0	−1·1	−1·4	+0·8	0·6	0·03	6·7	28·5	38·7	18·0	83·2
E. F. Ashley, London	04248	Single overcoil, s.r., fusee	−2·5	−0·7	+2·4	−0·5	+0·5	0·6	0·08	6·1	29·6	35·6	17·8	83·0
A. E. Fridlander, Coventry	52685	Double overcoil, d.r., g.h.	+3·2	+4·7	+4·6	+4·1	+4·1	0·8	0·03	5·2	27·4	37·3	18·3	83·0
J. White & Son, Coventry	34599	Single overcoil, s.r., g.h.	+0·8	+0·4	+1·2	+2·4	+1·2	0·5	0·07	4·7	29·9	37·5	15·5	82·9
J. White & Son, Coventry	34385	Double overcoil, d.r., g.b.	+2·2	+1·4	+3·6	+2·1	+3·6	0·5	0·06	5·2	29·8	38·6	16·0	82·6
Kean & Co., London	67112	Single overcoil, s.r., g.b.	+0·5	+0·0	−1·7	+1·4	+1·1	0·5	0·07	5·3	30·7	36·2	15·3	82·2
Jos. Player, Coventry	18074	Single overcoil, d.r., fusee	+5·1	+5·0	+4·2	−1·0	+4·2	0·6	0·06	6·7	28·0	38·4	15·7	82·1
J. White & Son, Coventry	34340	Single overcoil, d.r., g.b.	+0·9	−2·9	−0·4	+4·2	+0·5	0·5	0·06	6·0	30·9	38·0	15·8	81·9
Lancashire Watch Co.	979	Single overcoil, s.r., g.b.	+1·5	+1·6	−0·8	+3·6	+3·6	0·5	0·05	6·2	27·5	35·2	18·0	81·7
Stauffer, Son, & Co., London	134228	Single overcoil, s.r., g.b.	−0·4	−2·1	−2·9	−0·2	−0·2	0·5	0·04	5·0	29·9	35·8	15·9	81·6
A. E. Fridlander, Coventry	52578	Single overcoil, d.r., g.b., non magnetic	+3·0	+6·1	+4·9	+1·4	+4·5	0·6	0·01	6·5	27·6	34·4	19·2	81·2
A. E. Fridlander, Coventry	52791	Single overcoil, d.r., g.b.	+2·1	+0·4	+2·2	+4·0	+4·5	0·6	0·04	6·7	27·4	36·4	17·3	81·1
A. E. Fridlander, Coventry	52644	Single overcoil, d.r., g.b., non magnetic	+3·7	+2·9	−1·0	+4·9	+4·1	0·5	0·03	6·5	30·5	33·6	16·0	81·0
J. White & Son, Coventry	34300	Single overcoil, s.r., fusee	−0·4	+2·2	+1·2	+0·9	+0·6	0·5	0·03	6·8	30·2	37·4	14·3	81·0
Usher & Cole, London	26873	Single overcoil, s.r., g.b.	−0·9	+3·9	−2·4	−0·1	−3·0	0·6	0·03	8·5	30·2	32·7	18·0	80·9
J. White & Son, Coventry	33961	Single overcoil, s.r., g.b.	+3·7	+4·0	+1·8	+2·1	+2·1	0·5	0·09	8·2	30·6	35·9	14·3	80·8
A. E. Fridlander, Coventry	52794	Single overcoil, d.r., g.b.	−0·3	+2·6	+8·0	+2·1	−1·6	0·7	0·02	8·0	28·4	35·6	18·3	80·4
Rotherham & Sons, Coventry	07863	Single overcoil, s.r., g.b., chronograph	−2·0	+1·5	+1·2	+0·8	+0·6	0·7	0·03	7·7	22·0	34·0	18·3	80·8

Table I—*continued.*

Watch deposited by	Number of watch	Balance spring, escapement, &c.	Mean daily rate.					Mean variation of daily rate, *s.*	Mean change of rate for 1° F.	Difference between extreme gaining and losing rates.	Marks awarded for			Total Marks. 0—100.
			Pendant up.	Pendant right.	Pendant left.	Dial up.	Dial down.				Daily variation of rate.	Change of rate with change of position.	Temperature compensation.	
			secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.				
Rotherham & Sons, Coventry ...	13421	Single overcoil, s.r., g.b.	+5·4	+3·1	+8·1	+3·2	+1·8	0·9	0·07	7·2	28·8	36·7	15·3	80·8
P. Cohen, Coventry ...	108013	Single overcoil, s.r., g.b.	−3·2	−3·0	−0·0	−4·3	+0·2	0·5	0·01	7·2	29·0	33·1	19·7	80·9
Usher & Cole, London ...	27704	Single overcoil, s.r., fusee	+0·5	+3·0	+3·2	−0·9	+0·6	0·5	0·05	7·7	29·6	34·2	18·9	80·7
Rotherham & Sons, Coventry ...	94692	Single overcoil, s.r., g.b.	+1·2	+0·4	−0·6	+2·7	+3·0	0·7	0·02	6·0	23·4	35·2	18·9	80·6
Little & Co., London ...	2250	Single overcoil, d.r., g.b.	+2·9	+6·2	+4·0	+4·0	+4·4	0·9	0·05	7·5	27·2	34·8	16·4	80·4
J. White & Son, Coventry ...	83447	Single overcoil, d.r., g.b.	+0·7	−1·0	−0·7	+0·7	+1·7	0·4	0·12	7·3	31·6	36·4	12·3	80·3
H. Golay, London ...	2087	Double overcoil, d.r., g.b., minute repeater and minute chronograph	+0·8	−0·8	−0·2	+1·2	−0·2	0·8	0·05	8·0	24·0	37·3	18·1	80·3
Rotherham & Sons, Coventry ...	66463	Single overcoil, s.r., g.b	+0·4	+0·1	−0·7	−1·3	−0·4	0·7	0·07	7·5	26·2	37·6	16·4	80·3
Rotherham & Sons, Coventry ...	13414	Single overcoil, s.r., g.b.	+0·8	+0·1	−2·1	+0·1	+0·4	0·9	0·02	5·5	27·6	36·9	15·5	80·2
Penson & Son, Coventry ...	71164	Single overcoil, s.r., g.b., centre seconds	+0·1	+2·4	−0·8	−3·2	−0·2	0·7	0·06	9·0	25·1	35·2	18·9	80·2
Rotherham & Sons, Coventry —	97687	Single overcoil, s.r., g.b., chronograph ...	+2·7	+1·4	−1·4	+1·5	+1·9	0·6		5·7	28·6	35·8	15·7	80·1

In the above List, the following abbreviations are used, viz. :—s.r. for single roller; d.r. for double roller; g.b. for going barrel; + for gaining rate: — for losing rate.

APPENDIX III.—Table II.

Highest Marks obtained by Complicated Watches during the year.

Description of watch.	Number.	Received from.	Marks awarded for			Total marks, 0—100.
			Varia-tion.	Position.	Tempera-ture.	
Minute and seconds chronograph and minute repeater.........	2087	H. Golay, London	24·9	87·3	18·1	80·3
,, ,, ,,	4212	,, ,, ...	26·5	85·6	15·6	77·7
Minute and split seconds chronograph ...	74510	R. Roskell, Liverpool & London	25·7	35·8	16·5	78·0
,, ,, ,,	74522	,, ,,	28·6	27·4	15·1	71·1
,, ,, ,,	101—1892	S. Smith and Son, London ...	22·9	30·1	17·4	70·4
Minute and seconds chronograph	1477472	Stauffer, Son and Co., London	26·1	84·4	18·9	79·4
,, ,, ,,	13193	D. A. Nicole and Co., London.	27·3	32·4	18·1	77·8
,, ,, ,,	2085	Weill and Co., London.........	26·6	35·3	12·0	73·9
Ordinary seconds chronograph	97865	Rotherham and Sons, Coventry	26·5	36·0	18·3	80·8
,, ,, ,,	97867	,, ,,	28·6	35·8	15·7	80·1
,, ,, ,,	92488	,, ,,	23·5	37·8	15·7	77·0
Minute repeater.........	81946	G. Carley and Co., London....	24·8	38·0	13·4	76·2
,, ,, ,, ...	2078	H. Golay, London	25·7	36·8	12·0	74·5
,, ,, and clock-watch.........	52851	A. E. Fridlander, Coventry ...	25·1	32·4	15·3	72·8
"Non-magnetic" watches.........	52578	A. E. Fridlander, Coventry ...	27·5	34·4	19·3	81·2
,, ,, ,,	52844	,, ,,	30·5	33·6	16·9	81·0
,, ,, ,,	13131	S. Smith and Son, London....	23·1	34·3	19·0	76·4
,, ,, ,,	13405	Rotherham and Sons, Coventry	27·2	33·1	16·0	76·3

APPENDIX III.—Table III.

Abstract of Performance of Chronometers on Trial for the Italian Government, from June 1 to December 21, 1893.

Name of maker.	Number of chronometer.	Whether 2-day or 8-day.	Description of balance, &c.	Least weekly sum.	Mean temperature for that week.	Greatest weekly sum.	Mean temperature for that week.	Difference between the greatest and least. (a.)	Greatest difference between one week and the next. (b.)	Mean temperature for these two weeks.	Trial No. a + 2b
				secs.		secs.		secs.	secs.		secs.
V. Kullberg, London	5352	2	Auxiliary to balance; reversed detent	− 7·9	47·1	− 0·9	80·2	7·0	2·4	47·3 −45·4	11·8
J. E. A. Uhrig, "	587	2	Continually acting auxiliary	− 1·8	71·8	+ 8·3	81·4	10·1	3·2	67·1 −63·7	14·5
J. E. A. Uhrig, "	601	2	" " "	+ 6·2	63·6	+ 7·9	85·7	14·1	4·3	80·2 −87·3	22·7
A. W. Webb, "	5657	2	Ordinary balance	− 22·2	71·8	− 6·3	46·2	15·9	3·9	85·7 −80·2	23·7
A. W. Webb, "	5656	2	" "	− 10·9	69·0	+ 6·9	44·5	17·8	4·0	92·5 −96·9	25·8
D. Buckney, "	5635	2	Auxiliary to balance	− 7·6	96·9	+ 6·1	57·5	13·7	7·8	81·8 −92·2	28·3
V. Kullberg, "	5396	2	" " ; reversed detent	− 16·1	47·1	− 4·0	{92·5 / 81·8	12·1	8·6	57·5 −81·8	29·3
Kendal and Dent, "	5651	2	Ordinary balance	− 11·4	45·4	+ 3·5	80·2	14·9	7·4	80·2 −47·8	29·7
M. Klean and Co. "	1005 2	2	Auxiliary to balance	− 14·9	63·9	+ 2·4	78·4	17·3	7·5	75·0 −64·7	32·3
Kendal and Dent, "	8108	8	" acting in extremes	+ 0·9	63·6	+ 21·4	45·4	20·5	6·5	96·9 −84·8	33·5
V. Kullberg, "	5320	2	Auxiliary to balance; reversed detent	− 9·6	96·9	+ 8·6	80·2	18·2	8·2	96·9 −84·6	34·6
H. P. Isaac, "	1920 2	2	" bright spring	− 16·3	{45·4 / 45·4	+ 2·1	81·8	18·4	8·7	80·2 −47·8	35·8
Kendal and Dent, "	6587	2	" to balance, acting in extremes	+ 4·3	65·0	+ 20·6	{92·2 / 85·7	16·3	9·9	65·1 −85·4	36·1
H. P. Isaac "	1772	2	Auxiliary to balance, bright spring	− 3·8	96·9	+ 18·2	45·6	22·0	7·5	90·2 −47·8	37·0

30 movements were sent for this trial, but only the performance of those whose trial-number did not exceed 38 secs. is given above.

+ Rate gaining. — Rate losing.

The extreme range of temperature was from 37°·9 to 101°·2 F.

April 19, 1894.

The LORD KELVIN, D.C.L., LL.D., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

Professor Dewar made an oral communication stating that he had observed that many bodies cooled to between $-180°$ C. and $-200°$ C. after stimulation by light become remarkably phosphorescent, not only in increased intensity, but in duration, and that liquid oxygen itself always shows faint but distinct phosphorescence. He stated that the details of experiments would be shortly communicated to the Society.

The following Papers were read :—

I. "On an Anomaly encountered in Determinations of the Density of Nitrogen Gas." By LORD RAYLEIGH, Sec. R.S. Received February 16, 1894.

In a former communication[*] I have described how nitrogen, prepared by Lupton's method, proved to be lighter by about 1/1000 part than that derived from air in the usual manner. In both cases a red hot tube containing copper is employed, but with this difference. In the latter method the atmospheric oxygen is removed by oxidation of the copper itself, while in Lupton's method it combines with the hydrogen of ammonia, through which the air is caused to pass on its way to the furnace, the copper remaining unaltered. In order to exaggerate the effect, the air was subsequently replaced by oxygen. Under these conditions the whole, instead of only about one-seventh part of the nitrogen is derived from ammonia, and the discrepancy was found to be exalted to about one-half per cent.

Upon the assumption that similar gas should be obtained by both methods, we may explain the discrepancy by supposing either that the atmospheric nitrogen was too heavy on account of imperfect removal of oxygen, or that the ammonia nitrogen was too light on account of contamination with gases lighter than pure nitrogen. In-

[*] "On the Densities of the Principal Gases," 'Roy. Soc. Proc.,' vol. 53, p. 146, 893.

dependently of the fact that the action of the copper in the first case was pushed to great lengths, there are two arguments which appeared to exclude the supposition that oxygen was still present in the prepared gas. One of these depends upon the large quantity of oxygen that would be required in view of the small difference between the weights of the two gases. As much as 1/30th part of oxygen would be necessary to raise the density by 1/200, or about one sixth of all the oxygen originally present. This seemed to be out of the question. But even if so high a degree of imperfection in the action of the copper could be admitted, the large alteration caused by the substitution of oxygen for air in Lupton's process would remain unexplained. Moreover, as has been described in the former paper, the introduction of hydrogen into the gas made no difference, such hydrogen being removed by the hot oxide of copper subsequently traversed. It is surely impossible that the supposed residual oxygen could have survived such treatment.

Another argument may be founded upon more recent results, presently to be given, from which it appears that almost exactly the same density is found when the oxygen of air is removed by hot iron reduced with hydrogen, instead of by copper, or in the cold by ferrous hydrate.

But the difficulties in the way of accepting the second alternative are hardly less formidable. For the question at once arises, of what gas, lighter than nitrogen, does the contamination consist? In order that the reader may the better judge, it may be well to specify more fully what were the arrangements adopted. The gas, whether air or oxygen, after passing through potash was charged with ammonia as it traversed a small wash-bottle, and thence proceeded to the furnace. The first passage through the furnace was in a tube packed with metallic copper, in the form of fine wire. Then followed a wash-bottle of sulphuric acid by which the greater part of the excess of ammonia would be arrested, and a second passage through the furnace in a tube containing copper oxide. The gas then traversed a long length of pumice charged with sulphuric acid, and a small wash-bottle containing Nessler solution. On the other side of the regulating tap the arrangements were always as formerly described, and included tubes of finely divided potash and of phosphoric anhydride. The rate of passage was usually about half a litre per hour.

Of the possible impurities, lighter than nitrogen, those most demanding consideration are hydrogen, ammonia, and water vapour. The last may be dismissed at once, and the absence of ammonia is almost equally certain. The question of hydrogen appears the most important. But this gas, and hydrocarbons, such as CH_4, could they be present, should be burnt by the copper oxide; and the experiments already referred to, in which hydrogen was purposely introduced

into atmospheric nitrogen, seem to prove conclusively that the burning would really take place. Some further experiments of the same kind will presently be given.

The gas from ammonia and oxygen was sometimes odourless, but at other times smelt strongly of nitrous fumes, and, after mixture with moist air, reddened litmus paper. On one occasion the oxidation of the nitrogen went so far that the gas showed colour in the blow-off tube of the Töppler, although the thickness of the layer was only about half an inch. But the presence of nitric oxide is, of course, no explanation of the abnormal lightness. The conditions under which the oxidation takes place proved to be difficult of control, and it was thought desirable to examine nitrogen derived by *reduction* from nitric and nitrous oxides.

The former source was the first experimented upon. The gas was evolved from copper and diluted nitric acid in the usual way, and, after passing through potash, was reduced by *iron*, copper not being sufficiently active, at least without a very high temperature. The iron was prepared from blacksmith's scale. In order to get quit of carbon, it was first treated with a current of oxygen at a red heat, and afterwards reduced by hydrogen, the reduction being repeated after each employment. The greater part of the work of reducing the gas was performed outside the furnace, in a tube heated locally with a Bunsen flame. In the passage through the furnace in a tube containing similar iron the work would be completed, if necessary. Next followed washing with sulphuric acid (as required in the ammonia process), a second passage through the furnace over copper oxide, and further washing with sulphuric acid. In order to obtain an indication of any unreduced nitric oxide, a wash-bottle containing ferrous sulphate was introduced, after which followed the Nessler test and drying tubes, as already described. As thus arranged, the apparatus could be employed without alteration, whether the nitrogen to be collected was derived from air, from ammonia, from nitric oxide, from nitrous oxide, or from ammonium nitrite.

The numbers which follow are the weights of the gas contained by the globe at zero, at the pressure defined by the manometer when the temperature is 15°. They are corrected for the errors in the weights, but not for the shrinkage of the globe when exhausted, and thus correspond to the number 2·31026, as formerly given for nitrogen.

Nitrogen from NO by Hot Iron.

November 29, 1893	2·30143	
December 2, 1893........	2·29890	Mean, 2·30008
December 5, 1893........	2·29816	
December 6, 1893........	2·30182	

Nitrogen from N_2O by Hot Iron.[*]

December 26, 1893....... 2·29869 ⎱
December 28, 1893....... 2·29940 ⎰ Mean, 2·29904

Nitrogen from Ammonium Nitrite passed over Hot Iron.

January 9, 1894......... 2·29849 ⎱
January 13, 1894........ 2·29889 ⎰ Mean, 2·29869

With these are to be compared the weights of nitrogen derived from the atmosphere.

Nitrogen from Air by Hot Iron.

December 12, 1893...... 2·31017
December 14, 1893...... 2·30986 (H) ⎫
December 19, 1893...... 2·31010 (H) ⎬ Mean, 2·31003
December 22, 1893 ...... 2·31001 ⎭

Nitrogen from Air by Ferrous Hydrate.

January 27, 1894........ 2·31024 ⎫
January 30, 1894........ 2·31010 ⎬ Mean, 2·31020
February 1, 1894 .... 2·31028 ⎭

In the last case a large volume of air was confined for several hours in a glass reservoir with a mixture of slaked lime and ferrous sulphate. The gas was displaced by deoxygenated water, and further purified by passage through a tube packed with a similar mixture. The hot tubes were not used.

If we bring together the means for atmospheric nitrogen obtained by various methods, the agreement is seen to be good, and may be regarded as inconsistent with the supposition of residual oxygen in quantity sufficient to influence the weights.

Atmospheric Nitrogen.

By hot copper, 1892.......... 2·31026
By hot iron, 1893............ 2·31003
By ferrous hydrate, 1894...... 2·31020

Two of the results relating to hot iron, those of December 14 and December 19, were obtained from nitrogen, into which hydrogen had been purposely introduced. An electrolytic generator was inserted between the two tubes containing hot iron, as formerly described. The generator worked under its own electromotive force, and the current was measured by a tangent galvanometer. Thus, on December 19, the deflection throughout the time of filling was 3°, repre-

[*] The N_2O was prepared from zinc and very dilute nitric acid.

senting about 1/15 ampère. In two hours and a half the hydrogen introduced into the gas would be about 70 c.c., sufficient, if retained, to reduce the weight by about 4 per cent. The fact that there was no sensible reduction proves that the hydrogen was effectively removed by the copper oxide.

The nitrogen, obtained altogether in four ways from chemical compounds, is materially lighter than the above, the difference amounting to about 11 mg., or about 1/200 part of the whole. It is also to be observed that the agreement of individual results is less close in the case of chemical nitrogen than of atmospheric nitrogen.

I have made some experiments to try whether the densities were influenced by exposing the gas to the silent electric discharge. A Siemens tube, as used for generating ozone, was inserted in the path of the gas after desiccation with phosphoric anhydride. The following were the results :—

<div align="center">

Nitrogen from Air by Hot Iron, Electrified.

January 1, 1894......... 2·31163 ⎫ Mean, 2·31059
January 4, 1894......... 2·30956 ⎭

Nitrogen from N_2O by Hot Iron, Electrified.

January 2, 1894......... 2·30074 ⎫ Mean, 2·30064
January 5, 1894......... 2·30054 ⎭

</div>

The somewhat anomalous result of January 1 is partly explained by the failure to obtain a subsequent weighing of the globe empty, and there is no indication that any effect was produced by the electrification.

One more observation I will bring forward in conclusion. Nitrogen prepared from oxygen and ammonia, and about one-half per cent. lighter than ordinary atmospheric nitrogen, was stored in the globe for eight months. The globe was then connected to the apparatus, and the pressure was re-adjusted in the usual manner to the standard conditions. On re-weighing no change was observed, so that the abnormally light nitrogen did not become dense by keeping.

II. " On Variations observed in the Spectra of Carbon Electrodes, and on the Influence of one Substance on the Spectrum of another." By W. N. HARTLEY, F.R.S., Royal College of Science, Dublin. Received January 13, 1894.

In a recently published paper by Eder and Valenta, on the " Line Spectrum of Elementary Carbon and the Ultra-violet Spark Spectrum of Wet and Dry Wood Charcoal" (Vienna, ' Akad. Wiss. Denkschriften,' vol. 60, 1893), there occurs this passage :—

" It is worthy of remark that Hartley and Adeney, among the carbon lines measured by them, included those with wave-lengths 3881·9, 3870·7, 3589·9, and 3584·8, which, according to the foregoing investigation, are described as the edges of cyanogen bands, and must be struck out of the list of lines in the spectrum of carbon. Liveing and Dewar, in their previous work on the graphite spark spectrum, had not recorded them, but these were first presented as new carbon lines by Hartley and Adeney."

At the time the observations of Mr. Adeney and myself were made there was no published description of the ultra-violet spectrum of carbon, but before our work received publication, that of Messrs. Liveing and Dewar appeared, and to this we referred ('Roy. Soc. Proc.,' vol. 34, p. 429). The lines we described we still believe to be none other than carbon lines, because of the absence of satisfactory evidence to the contrary.

The carbon spectrum, as modified by moistening graphite electrodes and surrounding them with gases other than atmospheric air, was closely studied by me and the different spectra were mapped (' Phil. Trans.,' Part I, 1884, p. 49). Not only was the carbon spectrum studied, but an endeavour was made to obtain the " cyanogen bands " from saturated solutions of cyanides. No success attended these experiments, even when on the one hand a stable cyanide such as the potassium salt was used, nor when the most easily decomposed salt, mercuric cyanide, was taken. On this ground there appeared to be no sufficient reason for attributing the lines 3881·9, 3870·7, 3589·9, and 3584·8 to cyanogen rather than to carbon. On the other hand, it was shown that some of the lines were much strengthened and the general appearance of the first group was altered when concentrated solutions of zinc and calcium chlorides surrounded the electrodes, but it was evident that the modification of the spectrum did not arise from the zinc, calcium, or chlorine, and, therefore, more probably the carbon lines were modified by the presence of the saline solutions.

The stronger the solutions the more pronounced were the modifications in the spectra. Eder and Valenta do not appear to have referred to these facts, and it is quite possible they may have overlooked pp. 58 and 59 of my paper, where they are recorded and discussed.

I have recently again examined a large number of photographs of spectra of saline solutions and several spectra of various flames taken in the years 1880–81. The graphite electrodes immersed in solutions show beautiful groups of lines which coincide with the edges of certain bands in spectra of the flame of burning cyanogen. These bands can be recognised in the groups III and IV on the spectra photographed by Kayser and Runge.

The origin of these coincident portions of spectra, namely, from the combustion of cyanogen and from carbon electrodes in saline solutions, taken in conjunction with the fact that they are not rendered by cyanides, makes it doubtful whether the cyanogen spectrum is not due to elementary carbon, as first advocated by Marshall Watts. There are other facts and circumstances which somewhat support this doubt. First, variations have been observed in the spectrum of carbon which cannot be easily accounted for. Secondly, the effect of one substance on the spectrum of another which I have recently observed not only strengthens weak lines but in certain cases brings a new series of lines into view. Thirdly, the spectra of mixed vapours have been shown to be different from the spectra of the substances by themselves (Liveing and Dewar, 'Roy. Soc. Proc.,' vol. 34, p. 428); and, fourthly, the influence of the strong lines of an element on adjacent weaker lines of another substance is to strengthen the weaker lines in some cases, but almost to obliterate them in others.

In order the more readily to be able to refer to modifications in the carbon spectrum, I append lists of the lines which appear in different circumstances when condensed sparks are passed between graphite electrodes, so that at a glance it may be noted in what manner the spectra are modified. For comparison the edges of the cyanogen bands measured by Kayser and Runge, and the carbon lines as recorded by Eder and Valenta, are given. The difference between the wave-lengths quoted for the same lines is due chiefly to the different scales used, namely those of Ångström and of Rowland.

On examining these figures it will be observed that Hartley and Adeney's carbon line, 3881·9, may or may not coincide with the edge of the cyanogen band, 3883·6, of Kayser and Runge, but probably it does not. The carbon line, 3870·7 appears to coincide with 3871·7, the band of cyanogen, but there is no further agreement between the two spectra until we come to the three lines of carbon 3589·9, 3584·8, and 3583·5. The two lines 3881·9 and 3870·7 of carbon are obtained when dry electrodes are immersed in carbon dioxide, and under this condition the second line is greatly lengthened and both are much strengthened, whereas in atmospheric air, though the first is long, both are only feeble. With wet electrodes in air they are both long. With dry electrodes in oxygen 3881·9 is a long line, but 3870·7 is absent.

I conclude from these facts that, whatever may be the origin of these lines, they do not arise from the presence of any compound of carbon with nitrogen, while at the same time they do appear to belong to the element carbon.

Of the three lines given above, that with the wave-length 3589·9 appears when sparks are passed between dry electrodes of graphite

Variations in the carbon spectrum as observed in different circumstances.				Other spectra for comparison.	
Dry electrodes in air. (Hartley and Adeney.)	Dry electrodes in air. Ten lines absent. (Hartley.)	Dry electrodes in CO₂. Seven lines absent, others lengthened and strengthened. (Hartley.)	Dry electrodes in oxygen. Three lines absent, others lengthened, marked thus.* (Hartley.)	Edges of cyanogen bands. (Kayser and Runge, "Ueber die Spectren der Elemente," 'Königl. Preuss. Akad. Berlin,' 1889.)	Carbon lines. (Eder and Valenta, "Ueber das Emission-spectrum des Elementaren Kohlenstoffs." 'Kaiserl. Akad. Wissens. Vienna,' 1893.)
λ					
4266·8	absent	4266·8	4266·8	This is by far the strongest of the cyanogen bands 3883·6 edge	4267·5
3919·5	,,	3919·5	3919·5		3920·8
3881·9	,,	3881·9	3881·9		
3875·7	,,	3875·7	3875·7	3871·5 edge	
3870·7	,,	3870·7	absent	3590·5 edge	
3589·9	,,	absent	3589·9	3585·9	
3584·8		,,	absent	3584·0	
3583·5			,,		
3167·7	3167·7	3167·7	3167·7		
3166·0	3166·0	3166·0	3166·0		
2993·1	2993·1	absent	2993·1		2993·2
2967·3	2967·3	,,	2967·3		2967·6
2836·7	2836·7	2836·7	2836·7		2837·4
2835·9	2835·9	2835·9	2835·9		2836·2
2746·6	absent	absent	*2746·6		2747·3
2640·0			*2640·0		2641·4
2511·6	2511·6	2511·6	2511·6		2511·8
2508·7	2508·7	2508·7	2508·7		2508·0
2478·3	2478·3	2478·3	2478·3		2479·0
2297·7	2297·7	2297·7	*2297·7		2296·8

in an atmosphere of oxygen; this can scarcely be considered a cyanogen line. There remain now the two 3584·8 and 3513·5, and, as these lines are absent from the spectra taken in oxygen and in carbon dioxide, it may well be questioned whether their origin is elementary carbon.

From their occurrence in the spectra taken in air and their being lengthened when moistened electrodes are used, it seems that for their production nitrogen is necessary and water vapour advantageous; but they are not yielded by cyanides, and, therefore, in the absence of any good reason for this, they cannot be attributed to cyanogen. A further examination of the list of lines will show that there are seven attributed to carbon by Eder and Valenta and three assigned by them to cyanogen which do not always appear when powerful sparks are passed between graphite electrodes through air. Then we have four lines of carbon and three attributed to cyanogen which do not appear when the spark is passed through carbon dioxide. Liveing and Dewar ('Roy. Soc. Proc.,' vol. 34, p. 428) have shown that mixed vapours do not give precisely the same spectra as the substances present in the mixture would give by themselves. In certain cases one element renders the lines of another more brilliant, while in other instances some of the lines disappear. Chlorides usually have the effect of sweeping out the fainter lines.

The lines at 3590·5 and 3585·9 and 3584 are closely adjacent to certain nitrogen lines which are somewhat strengthened in the carbon spectrum. As the carbon spectrum varies remarkably under different conditions, it may exercise an influence on the nitrogen spectrum, and at the same time be modified by the presence of an atmosphere of this gas. In order to test the probability of the carbon and nitrogen spectra being subject to variations when the two elements are together in the spark or flame, it is necessary to consider the effect of one spectrum on another when the two are produced simultaneously from quite different materials.

In the oxyhydrogen flame the water-vapour lines are prominent, but only two groups are visible in the spectrum under normal conditions, and with an exposure of half an hour. If, however, some sulphur be burnt in the flame, the conditions being otherwise unchanged, then the spectrum, in addition to a band of continuous rays and flutings characteristic of sulphur vapour, shows the water-vapour lines wonderfully strong, with groups extending beyond those portions of the spectrum usually photographed, and not only are the lines distinct, but dense, as if their radiating power or the chemical action of their radiations was greatly increased. This does not arise from the continuous spectrum merely overlapping and apparently strengthening the water-vapour lines, since new groups of

lines came into view which were too feeble to be visible on the other photographs. Sulphur is not the only substance which affects this spectrum, for instance, the banded spectrum of magnesia and the spectrum of lime also appear to intensify it.

It is probable that something similar takes place with regard to carbon; we know that the spectrum is modified by the surrounding nitrogen of the atmosphere, and the rays of carbon increase the intensity of the nitrogen rays adjacent to the carbon lines, the effect being increased in the case of the spark by a saturated solution of zinc or calcium chloride.

The facts here set forth certainly favour the view that the lines in Hartley and Adeney's spectrum of carbon are the lines of the element and not merely the edges of cyanogen bands. Finally, I would point out that the carbon spectra of Eder and Valenta are not quite the same as those obtained by me, for if the photographs published in the 'Journal of the Chemical Society,' vol. 41, p. 91, are carefully examined with a strong magnifier, it will be seen that the graphite spectrum, No. 10, on Plate II, yields neither the group III nor group IV of cyanogen as depicted in spectrum No. 4 of the photogravure plate illustrating Eder and Valenta's paper; at the same time it may also be remarked that it does not resemble the spectrum of moistened electrodes to which I have already drawn attention.

III. "Electrical Interference Phenomena somewhat analogous to Newton's Rings, but exhibited by Waves along Wires." By EDWIN H. BARTON, B.Sc., late "1851 Exhibition" Science Scholar. Communicated by Professor ARTHUR W. RÜCKER, M.A., F.R.S. Received February 20, 1894.

(Abstract.)

1. The preliminary paper[*] on this subject gave the results of a single experiment, and approximately accounted for them by a mathematical theory of the phenomena involved.

2. The present paper discusses the question of disturbances, and gives nine experiments. Two of these are similar to the first experiment, but were made under better conditions; the others were made either to lead to these improved conditions or in confirmation of the original fundamental conclusions.

3. The disturbances alluded to arise from the fact that the electrical waves are not suddenly lost after their first incidence upon the abnormal part of the secondary, but course to and fro until they die out. A method of avoiding the greatest disturbance due to this cause is

[*] 'Roy. Soc. Proc.,' vol. 54, pp. 85—96, 1893.

pointed out and adopted. A correction is also calculated and applied for another disturbance which still remains.

4. The chief experiment* is on interference phenomena, somewhat analogous to Newton's rings, by transmission. The resultant curve† depends upon about 200 electrometer readings.

5. The experiments conclude with two examples‡ of modifications of the secondary which produce *no* reflexion. These consisted respectively of thinner wires nearer together, and of thicker wires further apart, than the normal spacing. In each case the capacity was practically unaltered by the change in the wires; hence, as anticipated from the theory, no reflexion occurred.

6. The systematic comparison of theory and experiment, made§ near the end of the paper, does not exhibit an absolute quantitative agreement. Nevertheless, the two are so far concordant in all their general features as to be mutually confirmatory, and were approved by Professor Hertz|| as close approximations.

IV. "On Rocks and Minerals collected by Mr. W. M. Conway in the Karakoram-Himalayas." By T. G. BONNEY, D.Sc., F.R.S., Professor of Geology in University College, London, and Miss C. A. RAISIN, B.Sc. Received February 15, 1894.

(Abstract.)

During his journey in the Karakoram-Himalayas, Mr. W. M. Conway collected more than 300 specimens of rocks and minerals, generally rather small, which have been examined by the authors. They give a general summary of the results obtained, together with the details of chief interest.

Among the rocks are numerous specimens of granite and gneiss (the latter frequently pressure-modified granites), diorites, and hornblende schists, crystalline limestones and dolomites, calc-mica, micaceous, and other schists, ordinary limestones, sandstones with some conglomerates, argillites, slates, and phyllites, as well as some peculiar mottled felstones, probably devitrified acid lavas, from one locality (Golden Throne Peak). Of these rocks, the most interesting are a dark green serpentine, very like a variety common in the Alps, some hornblendites, piedmontite-schists, schists with a secondary brown mica, the crystals in one case being quite a quarter of an inch in diameter; a partially altered argillaceous rock, in which small

---

* Expt. V, arts. 42—48.
† Curve E, fig. 10.
‡ Expts. VIII and IX, arts. 51—62.
§ Arts. 63—77.
|| Under whose able guidance the work was carried out in Bonn, 1892-93.

crystals of a mineral somewhat resembling ottrelite have been developed; a conglomerate, the matrix of which is rather altered, as in the case of certain " Huronian " conglomerates, and a black-garnet micaceous schist, exactly resembling a rock which occurs in the Lepontine Alps at various localities from the neighbourhood of the Lukmanior Pass to the Binnen-Thal.   Several of the schists resemble those which occur in the " upper schist " group (as defined by one of the authors) in the Alpine chain.   Certain rather fine-grained speckled gneisses resemble a variety of that rock common in the Blair Athol district (Scotland).

Among the minerals or vein-specimens, the most interesting is one which presents some resemblance to jadeite. Microscopic examination shows it to consist of an aggregate of minute minerals, very difficult to distinguish, and chemical analysis suggests that the most probable are lime-garnet, jadeite, saussurite, or an allied mineral, and a pyroxene. As the specimen was collected from a moraine, its origin is conjectural, but that it was a vein-specimen seems most probable.

The minerals (among others) are actinolite, garnet, idocrase, noble serpentine, pyrite, and copper ores.

The geographical distribution of the rocks is described, and it is shown that in these mountains, as in the Alps, remnants of sedimentary rocks, probably of more than one geological era, are folded in among great masses of crystalline rocks, some, doubtless of igneous origin, but others metamorphosed sediments. It is evident that here, also, the rocks, as a rule, have been greatly modified by the effects of earth-movements.

V. " Contributions to the Chemistry of Chlorophyll. No. V."
By EDWARD SCHUNCK, F.R.S.   Received February 15, 1894.

My previous papers were devoted to a description of various products derived from chlorophyll and their qualitative reactions. In the present communication I propose to give an account of some experiments made with a view to ascertain the composition of some of the derivatives of chlorophyll previously described.

Considerable difficulty was experienced in obtaining quantities of the various substances in a state sufficiently pure for analysis.   This was especially the case with phyllocyanin and phylloxanthin, which, by the methods of purification employed so far, cannot be obtained entirely free from fatty matter.   No attempt was therefore made to determine their composition.   Of the compounds of phyllocyanin there is one, the phyllocyanin cupric acetate, which crystallises well, and has the appearance of a definite compound.   Its composition was

accordingly determined, two analyses made by different observers leading to concordant results. Unfortunately, as previously explained, the compound is of such a nature as to make the elimination of copper and the consequent separation of the phyllocyanin impossible; otherwise the preparation of pure phyllocyanin from the compound would have been easy.

More satisfactory results were obtained in the case of phyllotaonin and its compounds. These beautiful substances being well crystallised and easily soluble in chloroform, but much less so in alcohol, may be obtained in a state of comparative purity, and I have reason to think that the numbers yielded by analysis represent, with tolerable accuracy, the composition of these bodies, although, in consequence of their high atomic weights, some doubt remains even as regards the corresponding empirical formulæ.

Phyllocyanin Cupric Acetate.

The preparation and properties of this compound have been previously described. Its analysis led to the following results.

I. 0·1221 gram substance gave 0·2715 CO_2 and 0·0577 H_2O.

　0·4226 „　　　„　　　„　17·8 c.c. N at 15° and 728·6 mm.

　0·2065 „　　　„　　　„　0·0236 CuO.

II. 0·4763 „　　　„　　　„　1·0550 CO_2 and 0·2315 H_2O.

These numbers correspond in 100 parts to

	I.	II.
C	60·64	60·40
H	5·25	5·39
N	4·74	—
Cu	9·12	9·07 *

The formula $C_{67}H_{71}N_5O_7Cu_2$ requires

C	60·27
H	5·33
N	4·49
Cu	9·52
O	20·39

Methylphyllotaonin.

The substance prepared in the manner formerly described, though apparently pure, was still contaminated with fatty matter, and had

* The details of the analysis yielding this percentage of Cu are unfortunately lost.

to be recrystallised several times in order to get it into a state fit for analysis. This process of purification, as well as the subsequent determinations, were undertaken by Dr. L. Marchlewski, whose scrupulous care and manipulative skill afford a sufficient guarantee for the accuracy of the results obtained.

I think it unnecessary to give the details of analysis of more or less pure specimens of the substance, but I may state that the crystals when first prepared gave the following percentages of C, H, and N.

$$
\begin{array}{ll}
\text{C} & 70.27 \\
\text{H} & 5.89 \\
\text{N} & 9.89 \\
\end{array}
$$

The substance, after being purified by dissolving it in chloroform, adding a large quantity of alcohol, and collecting the crystals deposited on standing, the process being repeated three times, gave as the result of two determinations 11·93 and 11·85 per cent. nitrogen. After three further crystallisations the percentage of nitrogen was found to be 12·07 and 11·87. The four analyses agreeing so well as regards the nitrogen it was assumed that the substance was pure, and it only remained therefore to determine the C and H, the results obtained being as follows :

I. 0·1521 gram substance gave 0·3838 CO_2 and 0·0852 H_2O.
II. 0·1877 „ „ „ 0·4745 „ „ 0·0998 „
III. 0·1284 „ „ „ 0·3246 „ „ 0·0683 „

In 100 parts

	I.	II.	III.
C	68·71	68·82	68·94
H	6·20	5·90	5 91

Taking the mean of the numbers given the composition of methylphyllotaonin would correspond to

$$
\begin{array}{ll}
\text{C} & 68.82 \\
\text{H} & 6.00 \\
\text{N} & 11.93 \\
\text{O} & 13.25* \\
\end{array}
$$

Ethylphyllotaonin.

In order to purify this substance the same method was adopted as in the case of methylphyllotaonin, *i.e.*, it was dissolved in chloroform

---

* Some time ago Mr. Percy C. Bell, working with a less pure specimen of methylphyllotaonin, found it to contain in 100 parts—

$$
\begin{array}{ll}
\text{C} & 68.87 \\
\text{H} & 6.46 \\
\end{array}
$$

and obtained in crystals on the addition to the solution of several times its volume of alcohol. After this process had been repeated several times two determinations yielded as a mean

$$
\begin{aligned}
&\text{C} \quad \ldots\ldots\ldots \quad 68\cdot73 \\
&\text{H} \quad \ldots\ldots\ldots \quad 5\cdot87 \\
&\text{N} \quad \ldots\ldots\ldots \quad 12\cdot33
\end{aligned}
$$

The substance having this composition was recrystallised four times in the same way as before, after which analysis led to the following results :—

I. 0·1407 gram substance gave 0·3571 CO_2 and 0·0762 H_2O.
II. 0·1020 „ „ 0·2589 CO_2 and 0·0560 H_2O.
III. 0·1002 „ „ 0·01143 gram N.

In 100 parts

	I.	II.	III.
C	69·22	69·22	—
H	6·01	6·07	—
N	—	—	11·40

Want of material prevented further attempts at purification. It will be seen that methylphyllotaonin and ethylphyllotaonin approach each other very closely in composition, as they also do in appearance and general properties.

Phyllotaonin.

This substance was obtained by saponification in the manner formerly described, partly from methylphyllotaonin, partly from ethylphyllotaonin. After drying at 130° analysis yielded the following results :

I. 0·1245 gram substance from methylphyllotaonin gave 0·3116 CO_2 and 0·0675 H_2O,
II. 0·1921 gram substance from ethylphyllotaonin gave 0·4884 CO_2 and 0·1062 H_2O.

In 100 parts

	I.	II.
C	68·26	68·76
H	6·02	6·14

Mr. W. Joséland made two analyses of phyllotaonin, the results being as follows :—

I. 0·2076 gram substance gave 0·5239 CO_2 and 0·1093 H_2O.
II. 0·2149 gram substance gave 24·10 c.c. N. at 22·5° and 951 mm.

In 100 parts

	I.	II.
C	68·82	68·61
H	5·85	5·88
N	12·85	—

Phyllotaonin Acetate.

This compound was prepared by dissolving phyllotaonin in boiling glacial acetic acid and allowing to crystallise.

0·1282 gram substance dried at 130° gave 0·3194 CO_2 and 0·0715 H_2O.

In 100 parts

C	67·95
H	6·17

In determining the C and H of this compound, Mr. Joseland obtained the following numbers :—

0·1425 gram substance gave 0·3564 CO_2 and 0·0754 H_2O.

In 100 parts

C	68·25
H	5·88

There are several formulæ with which the analyses of the derivatives of chlorophyll given above more or less closely agree, as will be seen from the following table :—

Phyllotaonin.

	Found.	Calculated. $C_{20}H_{19}N_3O_2(OH)$.	$C_{40}H_{38}N_6O_5(OH)$.	$C_{41}H_{41}N_6O_5(OH)$.
C	68·51	68·57	68·67	68·90
H	6·08	5·71	5·58	5·88
N	12·85	12·00	12·00	11·76

Methylphyllotaonin.

	Found.	Calculated. $C_{20}H_{19}N_3O_2(OCH_3)$.	$C_{40}H_{38}N_6O_5(OCH_3)$.	$C_{41}H_{41}N_6O_5(OCH_3)$.
C	68·82	69·23	69·00	69·23
H	6·00	6·04	5·74	6·04
N	11·92	11·54	11·77	11·53

Ethylphyllotaonin.

	Found.	Calculated.		
		$C_{20}H_{19}N_3O_2(OC_2H_5)$.	$C_{40}H_{38}N_6O_5(OC_2H_5)$.	$C_{41}H_{41}N_6O_5(OC_2H_5)$.
C	69·22	69·84	69·32	69·54
H....	6·04	6·35	5·91	6·19
N	11·40	11·11	11·55	11·32

Acetylphyllotaonin.

	Found.	Calculated.		
		$C_{20}H_{19}N_3O_2(OAc)$.	$C_{40}H_{38}N_6O_5(OAc)$.	$C_{41}H_{41}N_6O_5(OAc)$.
C	67·95	67·34	68·01	68·25
H....	6·17	5·61	5·53	5·82

VI. " Thermo-electric Properties of Salt Solutions." By GEORGE FREDERICK EMERY, B.A., LL.M., of the Inner Temple, late Scholar of Trinity College, Cambridge. Communicated by Professor J. J. THOMSON, F.R.S. Received February 8, 1894.

The thermo-electrical properties of solutions have not hitherto received much attention from physicists. If we form a circuit of two substances, one a metallic wire and the other a solution, and arrange it so that the junctions between the metal and the liquid are at different temperatures, we generally find that an electromotive force is developed in the circuit which varies in magnitude nearly in proportion to the difference of temperature between the junctions, and which, in comparison with the ordinary thermo-electromotive forces in metallic circuits, is very considerable. Up to the present time, as far as I am aware, the only extensive measurements of such thermo-electric forces are those of M. Bouty (' Journ. de Phys.,' vol. 9). He concludes that for a given difference of temperature between the junctions when the metal is constant the E.M.F. is nearly independent of the nature and strength of the solution (the solution being of some salt of the metal used).

The object of my experiments has been to see how far this is true, and to find out how (in the event of its not being strictly true) the E.M.F. varies with variations both in the strength and in the nature of the solution. The results show that both have considerable influence on the magnitude of the E.M.F.

My method of observation is as follows: the solution to be examined is put in a ∪-tube (fig. 1, A), in each limb of which is one of the ends of metal, which we may for convenience call electrodes, BB.

FIG. 1.

Close to each electrode is the bulb of a thermometer, C, graduated to one-fifths of a degree Centigrade. One limb of the ∪-tube is surrounded by a water-jacket, DD, which is heated by an ordinary circulating arrangement, so that its temperature can be regulated as desired. (See fig. 1.) The E.M.F. between the electrodes is balanced against a branch of a circuit of about 20,000 ohms through which a pair of Leclanché cells are kept closed, and the value of an ohm in E.M.F. is measured against a Clarke cell.

At the commencement of each experiment, when both electrodes were at the same temperature, there was very often a slight E.M.F between them. This was carefully read, and then the water-jacket was gradually heated and the readings of the thermometers were taken as the E.M.F. passed through, values represented by definite numbers of ohms generally differing by 5 or 10. The readings at the highest temperature were very carefully taken, and then the whole was allowed to cool, more readings being taken as the temperature fell. The value of any particular experiment is roughly given by the closeness of the readings for corresponding differences of temperature, while the temperature was rising and falling. In some series of observations the temperature was allowed to vary very slowly, so as

2 c 2

to give accurate readings all through and enable me to get a curve showing the connection between E.M.F. and difference of temperature. In every case this was very nearly a straight line, and most of the experiments were made pretty quickly so as to get accurate readings for the highest and lowest temperatures, while those for intermediate points served to show if any irregularity had taken place from secondary causes, and form a check on the accuracy of the whole. If the readings are not steady or differ much for corresponding points on rising and falling temperatures, I do not, as a rule, attach any value to that experiment. A change of $\frac{1}{16}°$ C. in the temperature of one of the junctions gave an easily noticeable deflection to the galvanometer spot.

For convenience I have used the symbol ϑ for the electromotive force per 1° C., and the unit in terms of which ϑ is given is 10^{-4} volts per 1° C.

The value of $d\vartheta/dt$ is in all cases very small compared with that of ϑ, and appears to vary in sign for different solutions.

Assuming, then, that $d\vartheta/dt = 0$, as is approximately the case, my object was to find the variation of ϑ with the strength of the solution.

I made a long series of experiments with six salts, acetate, chloride, and sulphate of zinc, and sulphate, nitrate, and acetate of copper. Nitrate of zinc and chloride of copper gave no results as they appeared to attack the electrodes. In a whole series of experiments on one salt I used the same lot of boiled distilled water and the same stock solution, which was diluted down to the required strength. I think, therefore, that any small effect due to impurities in the water may be safely taken to be a constant. The salts were all as pure as I could obtain, and the stock solution was kept for a long time over oxide or carbonate so as to neutralise any free acid as far as was possible.

I found considerable variations in the value of ϑ when the concentration of the solution was varied, and to show these I have plotted curves (fig. 2), whose ordinates are equal to ϑ, and abscissæ are the corresponding concentrations in gram molecules per litre of volume. For very small concentrations it seems impossible to observe ϑ accurately, and the parts of the curves corresponding to very small concentrations I have extra-polated as well as I can. For zero concentration the curves all appear to start from somewhere about $\vartheta = 8\cdot6$ at an angle to the axes, and then as concentration increases the curves bend round more or less sharply till they are nearly parallel to the axis of concentration. It will also be observed that for some salts ϑ increases with increasing concentration, while for others it decreases, so that for thermo-electrical purposes we may divide salts into positive and negative according as the value of ϑ for the solution is greater or less than its apparent value for pure water. In all the aqueous solutions

which I examined the current would go from hot to cold through the solution.

With the zinc salts I always used amalgamated zinc electrodes coated with sealing-wax or india-rubber where they entered the solution. I always found these very satisfactory; there was usually no E.M.F. between them when at the same temperature. Unamalgamated zinc is absolutely useless, as the E.M.F. flies about in a perfectly wild way. The following are the values found for ϑ:—

Chloride of Zinc in Water, A, fig. 2.

Concentration	= 0·4888	ϑ = 6·609
„	= 0·2444	ϑ = 6·868
„	= 0·1222	ϑ = 7·295
„	= 0·0611	ϑ = 7·89
„	= 0·0244	ϑ = 8·14
„	= 0·0122	ϑ = 8·3—8·4
Unknown „	strong	ϑ = 6·515

All the experiments on this salt were very satisfactory in every way.

Acetate of Zinc in Water, B.

Concentration	= 0·872	ϑ = 6·852
„	= 0·436	ϑ = 6·854
„	= 0·1744	ϑ = 7·17
„	= 0·0872	ϑ = 7·38
„	= 0·0436	ϑ = 7·55
„	= 0·022	ϑ = 7·9—8·1

This salt gave very satisfactory results.

Sulphate of Zinc in Water, C.

Concentration	= 0·525	ϑ = 8·95
„	= 0·261	ϑ = 8·8
„	= 0·0645	ϑ = 8·636
„	= 0·0161	ϑ = 8·55

This salt was not so satisfactory as those above, but the results are sufficient to show that the sulphate is thermo-electrically positive in aqueous solution.

With the copper salts I came to the conclusion, after trying several forms of electrode, that the most satisfactory consisted of a short length of fine wire projecting from the end of a glass tube, which was drawn out and stopped with shellac. The following results were obtained:—

Sulphate of Copper, D.

$$\text{Concentration} = 0\cdot6032 \quad \vartheta = 7\cdot8$$
$$\qquad\qquad = 0\cdot2011 \quad \vartheta = 8\cdot05$$
$$\qquad\qquad = 0\cdot1005 \quad \vartheta = 8\cdot3$$
$$\qquad\qquad = 0\cdot0402 \quad \vartheta = 8\cdot5$$

These were all very satisfactory. The value of ϑ for the strongest solution agrees with that found by M. Bouty.

Nitrate of Copper, E.

$$\text{Concentration} = 0\cdot384 \quad \vartheta = 6\cdot5$$
$$\qquad\qquad = 0\cdot192 \quad \vartheta = 6\cdot6—7$$
$$\qquad\qquad = 0\cdot096 \quad \vartheta = 7\cdot15—7\cdot31$$
$$\qquad\qquad = 0\cdot0384 \quad \vartheta = 7\cdot8$$
$$\qquad\qquad = 0\cdot0137 \quad \vartheta = 8\cdot5$$

Another stock solution gave—

$$\text{Concentration} = 0\cdot25 \quad \vartheta = 6\cdot618$$
$$\qquad\qquad = 0\cdot5 \quad \vartheta = 5\cdot583—5\cdot577$$
$$\qquad\qquad = 1\cdot0 \quad \vartheta = 6,\ \text{also } 7\cdot176—7\cdot083$$
$$\qquad\qquad = 2\cdot0 \quad \vartheta = 7\cdot018$$
$$\qquad\qquad = 4\cdot0 \quad \vartheta = 6\cdot39$$

These last very strong solutions do not seem to follow any rule, the last two were quite oily. The 0·25 concentration is the only one within the range of the first set of experiments with which it fits in very fairly.

Acetate of Copper, F.

$$\text{Concentration} = 0\cdot25 \quad \vartheta = 16\cdot4 \quad \text{It may be higher, but} < 17\cdot5$$
$$\qquad\qquad = 0\cdot125 \quad \vartheta = 14\cdot7 \quad \text{Varied from } 13\cdot7—15\cdot6$$
$$\qquad\qquad = 0\cdot0625 \quad \vartheta = 12\cdot1$$

This last of the copper salts was not at all satisfactory, but the results with it are very interesting, as the values of ϑ are all far above anything others measured. As the temperature rose the E.M.F. generally varied in an irregular way, rising at times more quickly than would be right, but as the temperature fell the E.M.F. usually fell pretty steadily, and the values deduced from the fall are those given ; they were all repeated, and the value given is what appears best. The value 12·1 for the last concentration was very steady.

After these experiments the solution stood in a stoppered bottle, and some bright blue crystals separated out of the liquid.

Fig. 2.

The results were somewhat changed by this, and the following were obtained, which though rather irregular show the great thermo-electric effect in this solution.

Acetate of Copper.

Concentration = 0·125	$\vartheta = 15$
,, = 0·0625	$\vartheta = 13$—16
,, = 0·05	$\vartheta = 15·6$—17·2
,, = 0·025	$\vartheta = 17·3$
,, = 0·01	$\vartheta = 17·1$
,, = 0·005	$\vartheta = 13·5$—15
,, = 0·0025	$\vartheta = 13·7$
,, = 0·001	$\vartheta = 10·1$

The weakest of these solutions gave the best results, it seemed as if the stronger the solution was the more irregular the E.M.F. became. All that can be said is that acetate of copper is very strongly thermoelectrically positive, and that a very minute quantity in water has a very great effect on the value of ϑ.

These experiments appear to show that a great part of the quantity ϑ is due to the water, and that the presence of a salt in solution may increase or diminish the value of ϑ according to the nature of the salt. The next step was to see how far this effect was an additive one, and for this various mixtures of the above salts were used. The value for water appears to be in the neighbourhood of $\vartheta = 8\cdot6$, but it cannot be measured directly, as with pure water the results are very irregular. The following table gives the value of ϑ as observed for the mixture, the values for the separate salts of the same strength, and the value which ϑ would have if water were $8\cdot6$ and the differences for the salts were additive.

ϑ observed.			ϑ single salts.	ϑ calculated.
$6\cdot3$ $6\cdot05$ $\Big\}=\Big\{$	$ZnCl_2$ $ZnAc_2$	$0\cdot2444$ $0\cdot436$	Conc. $= 6\cdot868$ „ $= 6\cdot854$	$\Big\}$ $5\cdot122$
$6\cdot473$ $6\cdot373$ $\Big\}=\Big\{$	$ZnCl_2$ $ZnAc_2$	$0\cdot1222$ $0\cdot218$	„ $= 7\cdot295$ „ $= 6\cdot97$	$\Big\}$ $5\cdot665$
$6\cdot28 = \Big\{$	$Cu(N_2O_3)_2$ $CuSO_4$	$0\cdot271$ $0\cdot2011$	„ $= 6\cdot75$ „ $= 8\cdot05$	$\Big\}$ $6\cdot2$
$6 = \Big\{$	$Cu(N_2O_3)_2$ $CuSO_4$	$0\cdot137$ $0\cdot1005$	„ $= 7\cdot2$ „ $= 8\cdot3$	$\Big\}$ $6\cdot9$
$8\cdot94 = \Big\{$	$Cu(N_2O_3)_2$ $CuAc_2$	$0\cdot125$ $0\cdot025$	„ $= 7$ „ $= 10—11\cdot3$	$\Big\}$ $8\cdot35—9\cdot65$
$7\cdot9 = \Big\{$	$CuAc_2$ $CuSO_4$	$0\cdot05$ $0\cdot3$	„ $= 7\cdot9$	
With brass—				
$6\cdot4 = \Big\{$	$ZnSO_4$ $CuSO_4$	$0\cdot174$ $0\cdot4022$		

These results show that though the difference from the water value of ϑ is not quantitatively additive, yet as far as direction is concerned the differences do add, with the exception of the mixture of copper sulphate and acetate, which turned quite milky during the heating, though there was no trace of irregularity in the change of E.M.F. In a case where the components are both negative ϑ for the mixture is below either of the ϑ's for the components, while for a mixture of a positive salt with a negative one the value of ϑ is between those for the components. It will be noticed that in all the mixtures the salts have one common component, so that there cannot be any action between the two salts. These results for mixtures of salts seem to be of value as supporting the theory that the final ϑ in a solution

is due to the superposing of a salt effect on that due to the water itself.

We see from these observations that for any given salt the value of ϑ, starting from some value independent of the nature of the salt, tends to come to some value depending on the salt, and which does not vary much for solutions of moderate strength. The latter result was that obtained by M. Bouty; the former is believed to be new. In one of his series of experiments M. Bouty used very strong solutions of zinc choride, and he found that as the strength of these was increased the value of ϑ rapidly diminished. This taken with the above results seems to show that, if we could trace the entire curve for this salt, taking the value of ϑ for all concentrations down to pure zinc choride at one end and pure water at the other, we should have a curve with a point of inflexion somewhere about its middle. It would, of course, be well-nigh impossible to trace such a curve for any salt, but we can do something very nearly identical without any great difficulty. If we take two solvents, and while keeping the salt a fixed quantity use different mixtures of the solvents, we can get a complete curve for ϑ, as it varies with the change of solvent. I made a large number of experiments on 1 per cent. solutions, or rather 1 gram per 100 c.c. solutions of cadmium bromide; these gave very good results with all the mixtures used. The electrodes were the exposed ends of sticks of cadmium, the sides being coated with glass. In each set I started with the solutions in pure solvents, and then mixed them so as to get the required mixture for each experiment.

With solutions of 1 gram per 100 c.c. in methyl alcohol and ethyl alcohol with their mixtures the following results were obtained :—

Methyl alcohol.	Ethyl alcohol.	ϑ (see fig. 3).
100·0	0	11·3
90·0	10·0	11·0
81·3	18·7	10·76
70·0	30·0	10·4—10·5
50·0	50·0	10·27
30·0	70·0	9·86
18·7	81·3	9·64
10·0	90·0	8·9
0	100·0	8·15

This gives us a curve with a point of inflexion similar to that suggested above as the probable shape of the complete curve for water and zinc choride.

Fig. 3.

Solutions of 1 gram of cadmium bromide per 100 c.c. in ethyl alcohol and water gave the following results :—

Ethyl alcohol.	Water.	Sp. gr.	ϑ (fig. 4).
0	100·0	1·00992	7·0
1·1	98·9	1·00384	6·86
10·0	90·0	0·99464	5·83
25·0	75·0	0·97825	5·053
50·0	50·0	0·93992	4·075
75·0	25·0	0·88472	4·123
100·0	0	0·81106	8·15

These results show a marked difference from those for mixtures of the two alcohols, methyl and ethyl. In the latter case we have an inflected curve, which is never far from the mean line which it would occupy, if ϑ for the mixture were proportionally placed between the ϑ's for the pure liquids. In the present case, however, a very small admixture of either with the other causes a large drop in the value of ϑ, and the curve lies almost entirely below its lower extremity. In both cases the ends are as symmetrical as the positions of the extremities will permit.

Now, the two pairs of solvents would appear to be good representatives of two classes of pairs of liquids. The two alcohols mix in a quiet way with no appearance of chemical action, or, if any, very little in the way of heat evolution and alteration of bulk, so that we might very well expect to find any property of the mixture not very different from the corresponding properties of the two components, and lying somewhere between them in value. In the case of a mixture of alcohol with water we have, on the contrary, large evolution of heat

FIG. 4.

and considerable alteration in bulk, so that we might expect to find a change in any physical property disproportionate to that usual in a case of simple mixture.

The variations in the value of ϑ for these two pairs are very like those in the conductivity of different pairs of metals, for here again we have in some cases the conductivity of the mixture nearly equal to the mean conductivity of the components, while for other pairs the conductivity of a mixture is far lower than that of either component.

Besides the above sets of experiments, observations on a constant strength of a stock solution of zinc sulphate mixed down to a constant bulk per 5 c.c. of stock with various substances, gave the following results.

Water only	$\vartheta = 8\cdot15$
10 per cent. alcohol..........................	$\vartheta = 7\cdot628$
20 „ „	$\vartheta = 7\cdot22$
30 „ „	$\vartheta = 6\cdot883$
40 „ „	$\vartheta = 6\cdot66$
10 grams sugar per 100 c.c.	$\vartheta = 8\cdot127$
45 „ „ „	$\vartheta = 8\cdot04$
10 c.c. of a sodic sulphate solution per 100 c.c.	$\vartheta = 7\cdot764$
20 „ „ „ „ „	$\vartheta = 7\cdot7$
30 „ „ „ „ „	$\vartheta = 7\cdot67$
20 „ „ „ „ $+$ 10 c.c.	
alcohol per 100 c.c.	$\vartheta = 7\cdot436$

All these were very satisfactory measurements. The zinc sulphate solution was not the same as that used before, and the value of ϑ for the aqueous solution is considerably lower than any of those previously obtained. The great alteration in the value of ϑ sometimes caused by comparatively slight changes in the quality of the solution makes it rather difficult to get the same results with two solutions which are apparently alike, and I do not think that this last value 8·15 need cause doubt as to the substantial accuracy of the previous results, since two at least of the previous set giving higher values for ϑ appeared to be free from any objection.

It will be noticed that all the additions to this zinc sulphate solution caused a decrease in the value of ϑ, that for sugar, as might be expected from such an inactive substance, being least and nearly proportional to its amount. The presence of the sodic sulphate has considerable effect on the value of the change caused by 10 per cent. alcohol, reducing the decrease in ϑ by about half its amount. The strength of the sodic sulphate added was too great to make the results very interesting, but I have no doubt that the curve would have come round to the zero at 8·15, like all the others.

Various strengths of cadmium bromide in alcohol, which was afterwards found not to be pure, were tried. The salt appeared to be pretty strongly positive, the values observed for ϑ being—

$$\text{For 0·4 per cent. solution } \vartheta = 5\cdot87$$
$$1\cdot0 \quad \text{,,} \quad \text{,,} \quad \vartheta = 7$$
$$4\cdot0 \quad \text{,,} \quad \text{,,} \quad \vartheta = 8\cdot115$$

1 gram cadmium bromide in 100 c.c. of normal propyl alcohol gave $\vartheta = 7\cdot48$.

A few experiments of what are believed to be an entirely novel kind were made on the thermoelectric force generated in a purely liquid circuit, that is, in a circuit composed of two kinds of liquid, the junctions being at different temperatures. To measure this E.M.F. one of the liquids was divided, and between the extremities, which were kept at exactly the same temperature, two similar electrodes were inserted. For this the following apparatus (fig. 5) was used.

The method of observation was as follows:—

The beakers A, A' contain No. 1 liquid, as does the tube C. Of two tubes D, of which the ends are closed by porous plates, D 1 contains No. 1 liquid, and D 2 contains No. 2 liquid. The tube D 1 was placed in position, and when the temperature was steady the E.M.F. between F, F', which were at the same temperature connected by one fluid was measured. Then the tube D 1 was removed, tube D 2 inserted, and the E.M.F. taken as soon as the temperature was steady.

Fig. 5.

AA′ are two beakers containing one of the liquids under examination, which we
   will call No. 1.
BB′ are two thermometers for telling the temperature of the liquid in the
   beakers.
 C is a bent tube full of No. 1 liquid, which is continuous between the end of
   C, which is under the liquid in A′, and in which the electrode F′ dips.
 D is a syphon tube connecting the liquids in AA′; it is full of liquid No. 2,
   and is closed at its ends by porous plugs, EE′, made of porous earthen-
   ware and fixed with shellac.
FF′ are the electrodes, F being in beaker A, and F′ in tube C, close to F, the
   bent part of C being in the beaker A.

The following results were obtained :—

With zinc sulphate 4 per cent. No. 1, zinc chloride weak as No. 2.
   $E/(t'-t) = 1.36 \times 10^{-4}$ V for two observations with temperature
   differences 36·4 and 29·4.

With zinc acetate as No. 2—

$$t'-t = 15.6 \qquad E/(t'-t) = 0.8 \times 10^{-4}\,V$$

$$t'-t = 28.0 \qquad E/(t'-t) = 1.05 \times 10^{-4}\,V$$

$$t'-t = 30.3 \qquad E/(t'-t) = 1.13$$

The latter are not so good as the first on zinc chloride, which gives
about what we might expect from the difference of the θ's of the two

salts. A few trials with alcohol in the D-tube were made, but were not very successful, owing to the rapid effects of diffusion in the A beaker constantly altering the E.M.F. at constant temperature.

Lastly, I endeavoured to prove by experiment that these thermo-electric forces at the junctions of metals and solutions are part of a system of reversible thermodynamic phenomena. For this to be true we require to prove the equation

$$\vartheta = dE/dt = H/t,$$

where H is the heat developed by the passage of unit of electricity across the junction, t is the absolute temperature of the junction, and ϑ is the quantity discussed above.

As far as I am aware, M. Bouty alone has attempted this previously ('Journ. de Phys.,' vol. 9). He used the plated bulbs of two similar thermometers as electrodes, noticing the difference between their readings when the current was allowed to pass in different directions. He graduated them in terms of heat units by sending a current through a spiral coil of fine wire enclosing one of the bulbs. The values of H which he so obtained compare fairly well with those of $t(dE/dt)$ measured directly. This method seems to depend rather too much on the steadiness of convection currents in a liquid to be quite reliable, and I have tried several arrangements to avoid this difficulty with, I think, satisfactory results.

Some very good observations were obtained with an apparatus on the ordinary calorimeter principle. It was made up of the following parts, fig. 6 :—

A. *The Measuring Apparatus.*—This consists of a double bobbin of thin sheet copper on a hollow core, on the lower end of which is screwed a metal plate (a), which forms the electrode, and is in close proximity all over its inner surface with the lower side of the bobbin. The lower half of the bobbin (β) is wound with very fine copper wire, the resistance of which forms the thermometer. The upper half of the bobbin (γ) is wound with platinoid wire, having a resistance of 9·58 ohms. This platinoid coil formed the heater, by means of which a known quantity of heat could be put into the calorimeter, and in this way its heat capacity could be measured.

B is a revolving stirrer which passes through the core of A, and rests on a thin metal plate.

The calorimeter vessel, C, is a thin glass tube, drawn out at its lower extremity, through which passes the stem of the lower electrode, D, which is a circular plate of metal; over D are porous plates, E, protected from the stirrer by a thin sheet of metal.

All the vessel above this sheet of metal is enclosed in a metal box F, and all above D is in a wooden box, G, which is surrounded on all sides by fossil meal.

Fig. 6.

The solution under examination is put in C, so as to cover A to a depth of half an inch, or thereabouts.

For measuring the current, the potential between the ends of a known resistance in its circuit was compared with a Clarke cell. Thus, if on the potentiometer the latter = S, the former = RC being T, we have

$$RC = (T/S)\ 1\cdot434\ \text{volt.}$$

For measuring the resistance, or rather the change in the resistance, of the coil B, a circular wire bridge, of what is believed to be a new form (fig. 7), which entirely avoids all thermoelectric disturbance, was used. The bridge wire, A, is on the inside wall of a circular channel, cut in a thick piece of wood. A second wire, B, made of the same material as A, is sprung into a groove on the outside wall of the channel. The ends of A are on two copper plates close together, and the ends of B are on a copper plate just opposite them, on the other side of the channel, so that all the junctions of dissimilar metals are within an area of about 1 sq. in. Contact is made between

Fig. 7.

A and B by a wire, C, of the same material, fixed on a handle, D, the position of which is read on a scale by a pointer, E. -

A switchboard was used which allowed a current to be sent in either direction through the liquid in the calorimeter, or through the coil, γ, or through both at once.

Two methods were employed with this apparatus for measuring the Peltier effect at a. The first is as follows.

After all has attained a uniform temperature, the resistance of β is measured. A current was then passed through γ for three minutes, the liquid being well stirred, and the current being measured. The resistance of β is again measured.

The whole is allowed to stand for a few minutes till the temperature is steady, and then a current is passed through the liquid by the plate a for three minutes, and the resistance of β is again measured. After a rest the current is reversed, and allowed to pass again through the liquid, and the resistance is again measured.

When the current is passing through the liquid the heating effect is due to two causes; one of these is unknown, and is independent of the direction of the current. Let C be the current, and let Ac^2 be this unknown heat. The rest is due to the Peltier effect, and we may put it equal to Hc.

Let d_1, d_2, d_3 be the changes in the resistance of β in the three observations, R the resistance of the platinoid coil γ, C_1 the current in the first, C that in the latter two observations. Then we have the following equations, since we may take d_1, d_2, d_3 proportional to the changes in the temperature :—

$$RC_1^2 = d_1 K$$

$$AC^2 + HC = d_2 K$$

$$AC^2 - HC = d_3 K$$

$$2HC = (d_2 - d_3)K$$

$$H = \frac{d_2 - d_3}{2d_1} \cdot \frac{C_1^2}{C} \cdot R$$

This is open to the objection that the heating not being the same in each case, the loss of heat will not be the same in each.

An improvement on this method which was afterwards adopted ensures the loss of heat being steady, and the same for all the observations. This was to so adjust the current that the change in the resistance of β should be the same, whether the current passed through the liquid, so as to heat the electrode a, or whether it passed so as to cool a, and at the same time passed through the coil γ.

If C is the current which gives these equal differences, we have

$$AC^2 + HC = dK = AC^2 - HC + RC^2,$$

or $$H = \tfrac{1}{2}RC.$$

The following observations were obtained with these methods, or combination of them, using a 15 per cent. solution of copper sulphate, for which the value of ϑ was equal to 6·8. The current is given in terms of potentiometer readings and the change of resistance in bridge divisions.

Current 311 through γ gives $d = 49·6$.
Current $+315$ through liquid gave $d = +11$.
   ,, -315 ,,   ,,   ,, $d = -39$, $-39·5$, -40, -43, and -46.

<div align="center">Mean, $-41·5$.</div>

<div align="center">Mean of first three, $-39·5$.</div>

$+11$ and $-41·5$ give $H = 0·1992$. $H/t = 6·94 \times 10^{-4}$.

$+11$ and $-39·5$,, $H = 0·1927$. $H/t = 6·72 \times 10^{-4}$.

Current -311 gave the same change of resistance as current $+306$ through liquid a coil γ,

whence $H = 0.1956,$

                           $H/t = 6.815 \times 10^{-4}.$

Current 335 by the second method gave perfectly constant change 34 of resistance for both directions of current,

whence $H = 0.2078,$

                           $H/t = 7.24 \times 10^{-4}.$

Finally, the measurement was reduced to a null method by using two pieces of apparatus like A, of the same size, and as nearly alike as possible. These were used side by side in a wooden bowl of liquid of an oblong shape, with a copper bottom, and divided by an ebonite plate, so that the current from the electrodes should go vertically through the liquid. Each platinoid coil had a resistance = 12·35 ohms., and the thermometer coils were 32 and 36 ohms. respectively. The total thickness of each bobbin with its electrode plate was not much above $\frac{1}{4}$ in., the diameter a little over 1 in.

The current passes through one of the γ coils, and from one electrode plate to the other through the bottom of the liquid. It is adjusted so that the ratio of the resistances of the thermometer coils should remain constant for both directions of current.

We now have, using the same letters as before, the single equation

$$AC^2 + HC = AC^2 - HC + RC^2,$$

assuming everything symmetrical,

or $H = \frac{1}{2}RC.$

If there is any want of symmetry, we shall get two values for C, one for each direction of the current, and if these are nearly equal, we are safe in taking their mean.

With this apparatus for the same solution a perfect balance was got in each direction for the same value of C = 0·0339 amp.

          $\therefore H = 6.165.$ $C = 0.2091$ volt amp.

                  $H/t = 7.26 \times 10^{-4}.$

As this seemed rather high, the contact of the electrodes with the bobbins was made better by amalgamating their surfaces.

A current 280 potentiometer gave a bridge change -10 in 5'.
  „   260   „   „   „   „   „ $+17$
          Mean 272·6 should give balance.

Current 272 gave perfect balance in each direction for different lengths of time.

This gives   H = 0·1952. t = 286.

$$H/t = 6·83 \times 10^{-4}.$$

This the last, and, I believe, the best, result, is almost exactly equal to ϑ for the solution.

With the last apparatus and a solution of nitrate of copper, for which ϑ was measured and found = 6·14, a perfect balance in both directions was obtained

with   C = 245   potentiometer

R = 1·05   „

S = 11·695   „

H = 0·1764. t = 288.

$$H/t = 6·1 \times 10^{-4}.$$

I should have liked to do a few more solutions, but something went wrong with the insulation of the bobbins, and I had no time to repair them. However, these two results appear to be enough to enable us to say that the equation

$$d\mathrm{E}/dt = \mathrm{H}/t$$

is true for the junctions of the kind under examination, and that these thermo-electric phenomena are reversible.

VII. " Experimental Determination of Poisson's Ratio." By C. E. STROMEYER. Communicated by LORD KELVIN, P.R.S. Received April 12, 1894.

The experiments with which this paper deals were carried out between the years 1883 and 1886 by Professor Kennedy and the author, with an instrument which the latter had originally designed for measuring local strains in metal structures, but which proved itself to be so exceedingly sensitive that it seemed capable of being applied to the measuring of the cross contraction of test pieces while these were subjected to a longitudinal pull, thus providing the means for measuring Poisson's ratio direct. In its original form the instrument consisted of two small frames, which were secured to each other by means of two flat springs, in such a manner, that any relative motion was a perfectly parallel one. One of these frames carried a small piece of dark glass, and close to it, but on the other frame, a right-angled reflecting glass prism was secured. The two glass surfaces, which faced each other, were then carefully adjusted, so as to

be nearly parallel, and, on throwing yellow sodium light into the prism, interference bands could be seen in the reflected light, and these would move either in one direction or the other, according as to whether the two glass surfaces, and with them their two frames, were either moving towards or away from each other. By counting the number of interference bands, which passed a mark which had been scratched on the dark glass, it was possible to estimate the amount of the relative motion of the two glass surfaces, each band representing a motion of half a wave-length of sodium light, or about 0·0000116 in. A centre point projected from the under-side of each frame, and these could be pressed against that part of the structure where it was intended to measure the variations of strains.

Subsequently these centre points were replaced by two small brackets and set screws, and in this form the instrument has been

FIG. 1.—Instrument A.

used in the following experiments. Fig. 1 shows a section through the instrument as altered, F_1 and F_2 are the two frames, S_1, S_2 are the flat springs holding them together and keeping them parallel, G is the black glass, P is the right-angled reflecting prism, and L the ray of sodium light. B_1 and B_2 are the two brackets, and T is the section of the test piece in position and ready for testing.

It was soon found that the results which were obtained with this instrument differed materially from those which were obtained by less direct methods; it was therefore taken to South Kensington and calibrated in a Whitworth measuring machine in company with Mr. Boys, by carefully comparing the relative motion of the two screws a and b, fig. 1, with the number of interference bands which had passed the mark on the dark glass. It was found that each band represented 0·0000144 in. Evidently the spring of the brackets and

FIG. 2.—Instrument B.

of the frames must account for this large difference, namely, 24 per cent., over the true value of 0·0000116 in. Although the cause might be known, this large correction introduced an element of uncertainty, which the author hoped to eliminate by constructing a new instrument, B, fig. 2.

In this sketch, T is the section of the test piece, which is pressed against the point on the frame F_1 by the screw S. G is the dark glass, which, as soon as T contracts, is pulled away from the glass prism P by means of the four helical springs Z, Z, which surround the columns C, C, and which are firmly secured to the frames F_2, F_3. The latter carry the adjustable glass prism P, which is so shaped that the ray of yellow sodium light L_1 does not fall together with its reflected ray L_2. The inclination of the rays of light in the narrow space between the prism P and the dark glass G was carefully measured, and found to be 19°, so that each interference band, as seen in the reflected yellow light, ought to represent a distance of 0·0000109 in., but careful measurements with the fine screw S showed

it to represent 0·0000120 in., or 10 per cent. more. Both instruments A and B were used, and in the Table each experiment is marked with a distinguishing letter. In the earliest experiments (marked A_1) a spirit lamp was used for illuminating purposes; it was enclosed in an asbestos-lined casing, but this soon got very hot, and must have affected the readings. Later on a Bunsen burner was used, and the test piece and instrument screened from its radiant heat. These experiments are marked A_2, but even now the heat made itself felt, and the value $1/\mu$, last column, might in most of the experiments, as well as those marked B_2, be reduced 5 per cent. In the case of those marked B_2, the test piece was placed in position and the lamp lit from 30 to 60 minutes before commencing the readings.

In most of the early experiments (compare Columns 3 and 4) five, ten, and even twenty bands were counted between each reading of the steelyard of the testing machine. This was not only very fatiguing to the eye, but it was subsequently impossible to determine whether any interference bands had been wrongly counted. In the later experiments, two, or at the utmost three, bands were counted for each steelyard reading. Judging by the results, the central position of each band can be estimated to within 10 per cent., and in many experiments the total number counted exceeded 20. Each test piece was strained to the maximum intended load before each experiment; but, in spite of this, the first experiments were always slightly unsatisfactory, and have generally been rejected.

The author's original intention had been to use the instrument A both for measuring the longitudinal extension and the cross contraction, but as this instrument did not give reliable results as regards extensions, other strain indicators had to be used.

I. Professor Kennedy's Lever Gear (C_1). The short end of a little lever ended in a point, which was inserted into the centre punch mark at one end of a test piece. The fulcrum was connected to an arm, which was fixed to the other end of the test piece, and the long arm of the lever acted as a pointer. The leverage was 100 to 1. This instrument measured the elongation only on one side of the test piece, and would not give reliable results. In many of the experiments (those marked C_2) the instrument was first fixed on one side of the test piece and then on the other. The same remarks apply to the following gear, D_1 and D_2.

II. Mr. Stromeyer's Rolling-pin Gear D_1. Two flat plates with projecting centre points at either end were attached to the test piece. The rolling pin, which was placed between the two plates, and held there by helical springs, was a fine piece of hardened steel wire, to which a large straw pointer was attached. In the first experiments *the leverage* was about 300 to 1; in the later ones it was nearly *1,000 to 1.*

Table.—Results of Experiments on Poisson's Ratio.

Reference No.	Material, sample number, diameter.	Number and nature of experiment.	Number of observations.	Instruments used.	Maximum stress of any experiment. (lbs.)	Mean stress for which values have been estimated. (lbs.)	E. (lbs.)	C. (lbs.)	σ. (lbs.)	Numbers of experiment rejected.	Poisson's ratio $\frac{1}{E} = \frac{1}{C}$ or $\frac{\mu}{2\sigma} - 1$.
1	B.B. iron (Northamptonshire). No. 75. Diam. 0·749".	2, tensile	22	C_1	22,000		27,670,000				
2		3, ,,	33	C_1	,,		30,000,000				
3		2, ,,	22	C_2	,,		27,450,000	102,200,000		1—5	0·279
4		3, ,,	18	A_2	24,000						
5		6, ,,	32	A_2	,,			102,700,000			
6	B.B. iron (Staffordshire). No. 5041. Diam. 1·054".	4, tensile	44	C_2	25,000		27,100,000	90,000,000		6, 7	0·301
7		5, ,,	26	A_2	26,000						
8	Bessemer steel (Cammel's). No. 32. Diam. 0·748".	2, tensile	34	C_1	40,000		30,675,000	115,500,000		8—10	0·279
9		6, ,,	28	A_2	41,000						
10		4, ,,	26	A_2	40,000			104,300,000			
11	Siemens-Martin steel (Leandore). No. 9050. Diam. 0·855".	2, tensile	28	C_1	40,000	10,500	29,700,000	108,600,000		11, 12	0·273
12		3, ,,	18	B_2	30,000 {	23,000		99,200,000		11, 13	0·300
13											
14	Cast (tool) steel. No. 5290. Diam. 1·008".	3, torsion	18	F	17,900				13,430,000	8, 11, 14	0·187

Table—*continued.*

Reference No.	Material, sample number, diameter.	Number and nature of experiment.	Number of observations.	Instruments used.	Maximum stress of any experiment. lbs.	Mean stress for which values have been estimated. lbs.	E. lbs.	C. lbs.	G. lbs.	Numbers of experiment selected.	Poisson's ratio $\frac{1}{\mu}=\frac{E}{C}$ or $\frac{C}{2G}-1$.
15	Chilled cast iron. Diam. 1".	4, tensile	110	D_2	6,200	..	21,350,000	..	6,700,000	15, 16	0·535
16		6, torsion	97	F	11,000	..	..				
17	Cast iron (turned). No. 820. Diam. 1·001".	7, tensile	98	C_2	12,400	3,560	10,890,000	:	:	17, 22	0·179
18						6,630	10,080,000	:	:	18, 22	0·165
19						9,690	9,460,000	:	:	19, 22	0·155
20						11,700	9,010,000	:	:	20, 22	0·146
21		4, „	20	$A_2 A_3$	13,000	..	..	72,000,000	:		
22		15 „	45		11,000	..	..	60,900,000	:		
23	Cast iron (turned). No. 5086. 1. Diam. 1·074".	2, tensile	24	D_3	18,000	3,500	17,180,000	:	:	23, 27	0·269
24						6,500	15,490,000	:	:	24, 27	0·243
25						9,500	13,730,000	:	:	25, 27	0·217
26						12,000	14,130,000	:	:	26, 27	0·222
27		4, „	24	A_3	10,700	..	..	63,800,000	:		
28	Cast iron (black). No. 5086. 2. Diam. 1·028".	3, tensile	9	D_2	13,000	2,000	17,200,000	:	:	28, 31	0·225
29						7,000	14,600,000	:	:	29, 31	0·216
30						13,000	12,800,000	:	:	30, 31	0·190
31		5 „	30	A_3	11,000	..	..	67,400,000	:		

Table—*continued.*

Reference No.	Material, sample number, diameter.	Number and nature of experiment.	Number of observations.	Instruments used.	Maximum stress of any experiment. lbs.	Mean stress for which values have been estimated. lbs.	E. lbs.	C. lbs.	σ. lbs.	Numbers of experiment selected.	Poisson's ratio $\frac{1}{\mu} = \frac{E}{C}$ or $\frac{E}{2C} - 1$.
32	Copper (best selected, rolled bar). No. 5070. Diam. 0·908".	4, tensile	40	C_1	20,000	...	16,700,000	52,900,000	...	32, 37	0·325
33		9, "	36	A_2	18,000	...	...	49,850,000	...	32, 38	0·319
34		8, "	19	A_2	15,000	...	...	56,100,000	...	32, 39	0·168
35		5, "	42	B_3	18,000	...	...	54,400,000	...		
36		8, "	48	B_3		...	...	51,500,000	...		
37		4, "	40	B_3	19,000	...	...	52,400,000	...		
38		4, compression	68	B_3	20,000	...	...	...	...		
39		2, torsion	80	F	12,900	...	...	...	7,300,000		
40	Cast copper. No 9703. Diam. 0·875".	1, tensile	18	E	11,000	...	17,070,000	...	...	40–42	0·366
41		1, compression	24	E	"	...	18,300,000	...	...		
42		4, tension	36	B_3	18,000	...	...	49,800,000	...		
43	Cast copper, No. 9703. Diam. 0·875".	1, tensile	32	E	11,000	...	18,520,000	...	...	43–45	0·380
44		1, compression	24	E	"	...	19,050,000	...	...		
45		4, tensile	36	B_3	10,000	...	...	49,400,000	...		
46	Bronze. No. 5212. Diam. 1·124".	4, tensile	28	$C_1 D_1$	12,000	...	11,580,000	35,800,000	...	46, 47	0·323
47		4, "	32	A_2	"	...	...	...	...		
48	Bronze. No. 5212. Diam. 1·124".	2, tensile.	22	C_1	20,000	...	11,330,000	37,000,000	...	48, 49	0·305
49		4, "	32	A_2	"	...	...	...	...		

Table—continued.

Reference No.	Material, sample number, diameter.	Number and nature of experiment.	Number of observations.	Instruments used.	Maximum stress of any experiment. lbs.	Mean stress for which values have been estimated. lbs.	E. lbs.	C. lbs.	σ. lbs.	Numbers of experiment selected.	Poisson's ratio $\frac{1}{\mu} = \frac{C}{E}$ or $\frac{E}{2C} - 1$.
50	Manganese bronze. (Forged) No. 4995. Diam. 1·000".	2, tensile	20	C_1	20,000	..	18,700,000	..	..	50, 51	0·241
51		4, „	16	A_4	„	..	..	40,260,000	..		
52	Manganese bronze. (Cold rolled.)	2, tensile	26	O_1	30,000	..	18,800,000	..	..	52, 53	0·386
53		5, „	20	A_2	27,000	7,500	..	42,400,000	..	52, 54	0·354
54						15,000	..	39,000,000	..	52, 55	0·363
55						23,000	..	38,100,000	..		
56	Delta metal. No. 5357. Diam. 1·007".	5, tensile	28	A_4	13,000	..	..	36,900,000	..	58, 60	0·568
57		3, „	22	B_2	„	..	..	31,700,000	..		
58		4, „	40	B_3	14,000	..	..	34,200,000	..	59, 60	0·525
59		3, compression	25	B_3	12,000	..	..	35,900,000	..		
60		5, torsion	27	F	9,000	..	..	..	6,160,000		
61	Muntz metal (Unannealed.) No. 5084. Diam. 0·975".	4, tensile	60	C_2	12,000	2,500	16,530,000	..	..	61, 66	0·357
62						5,500	14,930,000	..	..	62, 66	0·323
63						8,000	14,050,000	..	..	63, 66	0·304
64		4, „	16	A_3	12,000	10,000	13,700,000	..	..	64, 66	0·296
65						11,500	13,080,000	..	..	65, 66	0·268
66							..	46,300,000	..		

Table—*continued.*

Reference No.	Material, sample number, diameter.	Number and nature of experiment.	Number of observations.	Instruments used.	Maximum stress of any experiment.	Mean stress for which values have been estimated.	E.	C.	σ.	Numbers of experiment selected.	Poisson's ratio. $\frac{1}{E} = C$ or $\frac{\sigma}{2e} - 1$.
					lbs.	lbs.	lbs.	lbs.	lbs.		
67	Muntz metal. (Annealed.) No. 5085. Diam. 0·999".	3, tensile	36	C₂	12,000	9,560	14,100,000	38,900,000	..	67, 68	0·363
68						6,700	..	40,200,000	..	67, 69	0·351
69		4, „	16	A₂	13,000 {	10,000	..	43,600,000	..	67, 70	0·328
70							..		..		

NOTE.—E is Young's modulus, i.e., stress divided by the elongation of a unit of length.

C is the value of the fraction; stress divided by the cross contractions of a unit of the diameter.

σ is the value of the fraction; shearing stress divided by shearing angle.

No. 14. No tensile test was made in this case, and the mean value of Nos. 8 and 11 has been taken.

No. 15. This sample was so hard that it could not be machined, and the diameter could not be accurately ascertained.

Nos. 87—89. In order to make these three values agree, E should be 20,370,000.

Professor Kennedy's Needle Gear (E). Two frames were attached to either end of the test piece, and each one carried a long arm in such a position that the two were close alongside each other, but not touching. The index pointer was attached to a small brass frame from which two strong needle points, about one-tenth of an inch apart, projected; these rested in fine cross grooves which were cut on both arms, and any relative motion was magnified about a hundredfold. This instrument gives the average reading for two sides of a test piece.

One of the objects of these researches was, to ascertain whether Poisson's ratio, as determined by these experiments, agreed with the values as found by a comparison of tension and torsion tests, and in order to obtain reliable angular measurements of the twist, the author constructed an instrument (F), which consisted of two mirrors, which were attached to either end of a torsion test piece, in such a position that the doubly-reflected image of a scale, which was placed about 60 ft. away, coincided with the image as seen direct. A slight twist of the test piece produces a displacement of the two scales, and this is the measure of the torsion angle. The instrument is very sensitive and reliable for small angles.

Only a few of the samples were tested for torsion, but Messrs. Platt and Hargraves (Minutes of the Inst. of Civil Engineers, vol. xc, p. 387) have made experiments on 11 samples with the instruments C_1 and F, but as there is internal evidence that the results cannot be relied upon in all cases they have not been reproduced here.

Before discussing the results it will be necessary to consider how far the experiments are reliable. The instruments have already been discussed, but the methods also play an important part.

1st Method. Tensile test, measurement of elongation e and cross contraction c. The value of $1/\mu$ is c/e, and an error of 1 per cent. in either determination will affect $1/\mu$ by an equal amount.

2nd Method. Tensile test and measurement of elongation, and torsion test and measurement of shearing angle, α. In this case $1/\mu = \alpha\, 2e - 1$, and when this value is about 0·2, an error either in e or α produces a sixfold greater one in $1/\mu$. A 5 per cent. error in e, which is not unlikely, if it is only determined for one side, would absolutely spoil the conclusions. In most cases, $1/\mu$ found in this way is smaller than by the 1st Method, but, as will be seen (Table, Nos. 16 and 58), it sometimes is even greater than 0·500.

The conclusions to be drawn from the experiments with these nineteen samples are :—

1. That Poisson's ratio is not a constant value for all materials.

2. That mechanical treatment: cold rolling (No. 52) and annealing (No. 67) of the metal alter it.

3. That Poisson's ratio is sometimes a function of the stress (Nos. 12, 17, 23, 28, 53, 61, and 68).

4. That Poisson's ratio, as found by direct measurement, is not the same as that found by comparing torsion and tension experiments.

The work entailed in the digestion of these experiments, and their reduction to a small table, has been heavier than the author had anticipated, but as the results show that they are fairly reliable, they may be of use to those engaged in researches on elasticity. In conclusion, the author begs to thank Professor Kennedy, not only for allowing him the use of his testing machine, but also for directing each experiment, and personally taking its reading.

[April 30.—Somewhat similar experiments were carried out by Professor J. Bauschinger (see ' Der Civilingenieur,' 1879, 1881, 1882, &c.)].

Presents, April 19, 1894.

Transactions.

Alnwick :—Berwickshire Naturalists' Club. Proceedings. Vol. XIV. No. 1. 8vo. [*Alnwick* 1893]. The Club.

Austin :—Texas Academy of Science. Transactions. Vol. I. No. 2. 8vo. *Austin* 1893. The Academy.

Baltimore :—Johns Hopkins University. Circulars. Vol. XIII. No. 110. 4to. *Baltimore* 1894. The University.

Belgrade :—Royal Servian Academy. Glas. 41–42. [*Servian.*] 8vo. *Belgrade* 1894; Godishnak. 1889–90. [*Servian.*] 8vo. *Belgrade* 1890–91; Geology of Servia. Atlas. Part 1. [*Servian.*] 4to. *Belgrade* 1893. The Academy.

Berlin :—Gesellschaft für Erdkunde. Verhandlungen. Bd. XXI. Nos. 2–3. 8vo. *Berlin* 1894; Zeitschrift. Bd. XXVIII. No. 6. 8vo. *Berlin* 1893. The Society.

K. Preuss. Akademie der Wissenschaften. Sitzungsberichte. 1893. Nos. 39–53. 8vo. *Berlin* 1893. The Academy.

Bremen :—Naturwissenschaftlicher Verein. Abhandlungen. Bd. XIII. Heft 1. 8vo. *Bremen* 1894. The Society.

Bucharest :—Societății de Sciințe Fizice. Buletinul. Anul II. Nos. 11–12. 8vo. *Bucuresci* 1893. The Society.

Buda-Pesth :—Kön. Ungarische Geologische Anstalt. Földtani Közlöny. Kötet XXIII. Füzet 9–12. 8vo. *Budapest* 1893; Mittheilungen. Bd. X. Heft 4–5. 8vo. *Budapest* 1894. The Institute.

Cambridge :—Cambridge Philosophical Society. Transactions. Vol. XV. Part 4. 4to. *Cambridge* 1894. The Society.

Cambridge, Mass. :—Museum of Comparative Zoology. Bulletin. Vol. XXV. Nos. 5–6. 8vo. *Cambridge* 1894. The Museum.

Transactions (*continued*).

Coimbra:—Universidade. Annuario. 1893.-94. 8vo. *Coimbra* 1894. The University.

Cracow:—Académie des Sciences. Bulletin International. Février, 1894. 8vo. *Cracovie.* 'The Academy.

Essex:—Essex Field Club. The Essex Naturalist. Vol. VII. Nos. 10–12. 8vo. *Chelmsford* 1894. The Club.

Frankfort-on-the-Oder:—Naturwissenschaftlicher Verein. Helios. Jahrg. XI. Nos. 10–12. 8vo. *Frankfurt a. O.* 1894; Societatum Litteræ. Jahrg. VIII. Nos. 1–3. 8vo. *Frankfurt a. O.* 1894. The Society.

Göttingen:—Königl. Gesellschaft der Wissenschaften. Nachrichten. 1893. Nos. 15–21. 1894. No. 1. 8vo. *Göttingen* 1893–94. The Society.

Jena:—Medizinisch-naturwissenschaftliche Gesellschaft. Jenaische Zeitschrift für Naturwissenschaft. Bd. XXVIII. Heft 3. 8vo. *Jena* 1894. The Society.

Kharkoff:—Section Médicale de la Société des Sciences Expérimentales. Travaux. 1892–93. [*Russian.*] 8vo. *Kharkoff* 1892–93. The Society.

Klausenburg:—Erdélyi Muzeum-Egylet. Értesitő. Évfol. XVIII. Section 1. Füzet 2–3. 8vo. *Kolozsvárt* 1894.

The Society.

Leeds:—Yorkshire College. Annual Report. 1892–93. 8vo. *Leeds.* The College.

Leipsic:—Königl. Sächs. Gesellschaft der Wissenschaften. Berichte über die Verhandlungen (Phil.-hist. Classe). 1893. Nos. 2–3. 8vo. *Leipzig* 1894. The Society.

Liége:—Société Géologique de Belgique. Annales. Tome XXI. Livr. 1. 8vo. *Liége* 1893–94. The Society.

London:—British Astronomical Association. Journal. Vol. IV. No. 4. 8vo. *London* 1894; Memoirs. Vol. II. Parts 4–5. 8vo. *London* 1894. The Association.

British Museum. Catalogue of Sanskrit, Pali, and Prakrit Books acquired during the years 1876–92. 4to. *London* 1893; Catalogue of Cuneiform Tablets. Vol. III. 8vo. *London* 1893; Catalogue of English Coins: Anglo-Saxon Series. Vols. I—II. 8vo. *London* 1887–93; Catalogue of Printed Books. Peter—Présomptions. 4to. *London* 1894.

The Museum.

Camera Club. Journal. Vol. VIII. Nos. 92–95. 8vo. *London* 1894; Catalogue of the Library. Second edition. 8vo. *London* 1893. The Club.

Institute of Brewing. Transactions. Vol. VII. No. 5. 8vo. *London* 1894. The Institute.

Transactions (*continued*).

Institution of Civil Engineers. Minutes of Proceedings. Vol CXV. 8vo. *London* 1894. The Institution.

Institution of Mechanical Engineers. Proceedings. 1893 No. 4. 8vo. *London* [1894]. The Institution.

Linnean Society. Journal (Botany). Vol. XXX. No. 207. 8vo. *London* 1894. The Society.

Odontological Society. Transactions Vol. XXVI. Nos. 4–5. 8vo. *London* 1894. The Society.

Photographic Society of Great Britain. Journal and Transactions. Vol. XVIII. No. 7. 8vo. *London* 1894.

The Society.

Quekett Microscopical Club. Journal. Vol. V. No. 34. 8vo. *London* 1894. The Club.

Royal Agricultural Society. Journal. Vol. V. Part 1. 8vo. *London* 1894. The Society.

Royal Institution of Great Britain. Proceedings. Vol. XIV. Part 1. 8vo. *London* 1894; List of the Members, Officers, and Professors. 1893. 8vo. *London* 1893.

The Institution.

Royal Statistical Society. Journal. Vol. LVII. Part 1. 8vo. *London* 1894. The Society.

Royal United Service Institution. Journal. Vol. XXXVIII. No. 193. 8vo. *London* 1894. The Institution.

Sanitary Institute. Transactions. Vol. XIV. 8vo. *London* 1894; Journal. Vol. XV. Part 1. 8vo. *London* 1894.

The Institute.

Society of Antiquaries. Archæologia. Vol. LIII. 4to. *London* 1893; Proceedings. Vol. XIV. No. 4. 8vo. *London* [1893]; Index of Archæological Papers published in 1892. 8vo. *London* 1893. The Society.

Lund:—Universitet. Ars-Skrift. Tom. XXIX. 4to. *Lund* 1892–93. The University.

Manchester:—Geological Society. Transactions. Vol. XXII. Part 15. 8vo. *Manchester* 1894. The Society.

Melbourne:—Exhibition Building. Illustrated Official Handbook to the Aquarium, Picture Galleries, and Museum Collections. 8vo. *Melbourne* 1894. The Trustees.

Munich:—K.B. Akademie der Wissenschaften. Sitzungsberichte (Math.-phys. Classe). 1893. Heft 3. 8vo. *München* 1894.

The Academy.

Naples:—Accademia delle Scienze Fisiche e Matematiche. Rendiconto. Anno XXXIII. Fasc. 1—2. 4to. *Napoli* 1894.

The Academy.

Transactions (*continued*).

Newcastle-upon-Tyne:—North of England Institute of Mining and Mechanical Engineers. Transactions. Vol. XLII. Part 5. Vol. XLIII. Parts 2—3. 8vo. *Newcastle-upon-Tyne* 1893.

The Institute.

Odessa:—New Russian Society of Naturalists. Zapiski. Tom. XVIII. Part 1. [*Russian.*] 8vo. *Odessa* 1893; Zapiski (Mathematical Section). Tom. XV. [*Russian.*] 8vo. *Odessa* 1893.

The Society.

Oxford:—Radcliffe Library. Catalogue of Books added during the year 1893. 4to. *Oxford* 1894. The Trustees.

Paris:—École Normale Supérieure. Annales Scientifiques. Tome XI. Nos. 2—4. 4to. *Paris* 1894. The School.

Faculté des Sciences. [Thèses soutenues pendant l'année 1893.] 8vo. and 4to. *Paris* 1893. The Faculty.

Société de Géographie. Bulletin. Tome XIV. Trim. 3. 8vo. *Paris* 1894. The Society.

Société Mathématique. Bulletin. Tome XXII. Nos. 1—2. 8vo. *Paris* [1894]. The Society.

Société Philomathique. Bulletin. Tome VI. No. 1. 8vo. *Paris* 1894. The Society.

Rome:—Accademia Pontificia de' Nuovi Lincei. Atti. Anno XLV. Sessioni 3—6. 4to. *Roma* 1892. The Academy.

Rothamsted:—Rothamsted Jubilee Fund. Report of the Executive Committee, with an account of the Proceedings at the Commemoration of the Jubilee of the Rothamsted Experiments, July 29th, 1893. 8vo. *London* [1894]; Portrait on India paper of Sir J. B. Lawes, from a painting by Mr. H. Herkomer, R.A. The Executive Committee of the Fund.

St. Petersburg:—Académie Impériale des Sciences. Mémoires. Tome XLI. Nos. 2—5. 4to. *St. Pétersbourg* 1893.

The Academy.

San Francisco:—California Academy of Sciences. Memoirs. Vol. II. No. 3. 4to. *San Francisco* 1894. The Academy.

Santiago:—Sociedad Nacional de Mineria. Boletin. Año X. No. 63. 4to. *Santiago de Chile* 1893. The Society.

Siena:—R. Accademia dei Fisiocritici. Atti. Vol. VI. Fasc. 1. 8vo. *Siena* 1894; Processi Verbali delle Adunanze. No. 1. 8vo. *Siena* 1894. The Academy.

Stockholm:—Kongl. Vetenskaps Akademie. Öfversigt. Arg. LI. No. 1. 8vo. *Stockholm* 1894. The Academy.

Sydney:—Australian Museum. Catalogue of the Australian Birds. Part 4. 8vo. *Sydney* 1894. The Trustees.

Toronto:—Astronomical and Physical Society. Transactions. 1893. 8vo. *Toronto* 1894. The Society.

Transactions *(continued)*.

Vienna:—Anthropologische Gesellschaft. Abhandlungen. Bd. XXIV. Heft 1. 4to. *Wien* 1893. The Society.

K. Akademie der Wissenschaften. Denkschriften. Bd. LX. 4to. *Wien* 1893; Sitzungsberichte (Math.-naturw. Classe). Bd. CII. Abth. 1. Hefte 8—10. Abth. 2a. Hefte 9—10. Abth. 2b. Hefte 9—10. 8vo. *Wien* 1893. The Academy.

K.K. Geographische Gesellschaft. Mittheilungen. Bd. XXXVI. 8vo. *Wien* 1893. The Society.

Washington:—Smithsonian Institution. Annual Report of the Board of Regents. 1891. 8vo. *Washington* 1893.
The Institution.

U.S. Department of Agriculture. Experiment Station Bulletin. Nos. 15, 17. 8vo. *Washington* 1893; Experiment Station Record. Vol. V. Nos. 6—7. 8vo. *Washington* 1894.
The Department.

Würzburg:—Physikalisch-Medicinische Gesellschaft. Verhandlungen. Bd. XXVII. No. 5. 8vo. *Würzburg* 1893; Sitzungs-Berichte. Jahrg. 1893. Nos. 10—11. 8vo. *Würzburg* 1893.
The Society.

Observations and Reports.

Adelaide:—Observatory. Meteorological Observations. 1886–7. Folio. *Adelaide* 1893. The Observatory.

Berlin:—Commission des Venus-Durchgangs. Die Venus-Durchgänge 1874 und 1882. Bericht über die Deutschen Beobachtungen. Bd. V. 4to. *Berlin* 1893. The Commission.

Bombay:—Government Observatory. Magnetic and Meteorological Observations. 1891–92. 4to. *Bombay* 1893.
The Observatory.

Calcutta:—Meteorological Department, Government of India. Meteorological Observations recorded at Seven Stations in India. October, 1893. 4to; Monthly Weather Review. October, 1893. 4to. *Calcutta,* 1894. The Department.

Edinburgh:—Royal Observatory. Circular. No. 41. 4to [sheet]. 1894. The Observatory.

International:—Observations Internationales Polaires, 1882–83. Expédition Danoise; Observations faites à Godthaab. Tome I. Livr. 1. 4to. *Copenhague* 1893. The Meteorological Office.

Kiel:—Sternwarte. Publication. 9. 4to. *Kiel* 1894.
The Observatory.

Madrid:—Observatorio Astronómico. Treinta Años de Observaciones Meteorológicas, 1860–89. Oblong. *Madrid* 1893.
The Observatory.

Observations and Reports (*continued*).

Milan:—R. Osservatorio Astronomico di Brera. Osservazioni Meteorologiche. 1893. 8vo. *Milano* [1894].

The Observatory.

Switzerland:—Schweizerische Geodätische Commission. Das Schweizerische Dreiecknetz. Bd. VI. 4to. *Zürich* 1894.

The Commission.

Sydney:—Observatory. Results of Raiń, River, and Evaporation Observations. 1892. 8vo. *Sydney* 1893; Diagram of Isothermal Lines of New South Wales. 8vo; Meteorological Observations. October, 1893. 8vo. [*Sydney*]; [And 4 Excerpts. 8vo.]

The Observatory.

Upsala:—Observatoire Météorologique. Bulletin Mensuel. Vol. XXV. 4to. *Upsal* 1893–94.

The Observatory.

Washington:—U.S. Coast and Geodetic Survey. Bulletin. No. 25. 4to. *Washington* 1892.

The Survey.

U.S. Department of Agriculture. Monthly Weather Review. December, 1893—January, 1894. 4to. *Washington* 1894.

The Department.

Journals.

Agricultural Gazette of New South Wales. Vol. V. Parts 1—2. 8vo. *Sydney* 1894. Department of Agriculture, Sydney.

Asclepiad. Vol. X. No. 40. 8vo. *London* 1893.

Sir B. W. Richardson, F.R.S.

Astronomical Journal. Vol. XIV. No. 1. 4to. *Boston, Mass.* 1894. Smithsonian Institution, Washington.

Astronomische Nachrichten. Bd. CXXXIV. 4to. *Kiel* 1894.

The Observatory, Kiel.

Boletin de Minas Industria y Construcciones. Año IX. No. 12. 4to. *Lima* 1893. Escuela Especial de Ingenieros, Lima.

Cellule (La). Tome X. Fasc. 1. 8vo. *Louvain* 1894.

The Editors.

Dentists Register. 1894. 8vo. *London.*

General Medical Council.

Fortschritte der Physik. Jahrg. XLIII. (1887). 8vo. *Berlin* 1893–94. Physikalische Gesellschaft, Berlin.

Horological Journal. Vol. XXXVI. No. 428. 8vo. *London* 1894.

British Horological Institute.

Mathematical Questions and Solutions from the 'Educational Times.' Vol. LX. 8vo. *London* 1894. Mr. W. J. C. Miller.

Medical Register. 1894. 8vo. *London.*

General Medical Council.

Morphologisches Jahrbuch. Bd. XXI. Heft 1. 8vo. *Leipzig 1894.*

The Editor.

Journals (*continued*).
Nature Notes. Vol. V. No. 52. 8vo. *London* 1894.

<div align="right">Selborne Society.</div>

Revue Médico-pharmaceutique. Année VII. No. 2. 4to. *Constantinople* 1894.

<div align="right">The Editor.</div>

Stazioni Sperimentali Agrarie Italiane. Vol. XXVI. Fasc. 2. 8vo. *Modena* 1894.   R. Stazione Agraria, Modena.

Timehri: Journal of the Royal Agricultural and Commercial Society of British Guiana. Vol. VII. Part 2. 8vo. *Demerara* 1893.

<div align="right">The Society.</div>

Zeitschrift für Biologie. Bd. XXX. Heft 4. Bd. XXXI. Heft 1. 8vo. *München* 1894.

<div align="right">The Editors.</div>

Burdett (H. C.) Burdett's Official Intelligence. 1894. 4to. *London.*

<div align="right">The Author.</div>

Dawson (Sir J. W.), F.R.S. New Species of Cretaceous Plants from Vancouver Island. 4to. [*Ottawa* 1893.]   The Author.

Dukes (C.) On the Features which distinguish Epidemic Roseola (*Roserash*) from Measles and Scarlet Fever. 8vo. *London* 1894.

<div align="right">The Author.</div>

Fritsche (H.) Die magnetischen Localabweichungen bei Moskau und ihre Beziehungen zur dortigen Local-Attraction. 8vo. [*Moskau* 1894.]   The Author.

Gallois-Dechaume (A.) Trisection de l'Angle à l'Aide de la Règle et du Compas. 4to. [*Manuscript.*]   The Author.

Gladstone (J. H.), F.R.S. Ancient Metals from Tell-el-Hesy. 8vo. *London* 1894.   The Author.

Gore (G.), F.R.S. Changes of Temperature caused by Contact of Liquids with Powdered Silica, &c. 8vo. *London* 1894.

<div align="right">The Author.</div>

Greenhill (A. G.), F.R.S. A Treatise of Hydrostatics. 8vo. *London* 1894.   The Author.

Guppy (H. B.) River Temperature. Part 1.—Its Daily Changes and Method of Observation. 8vo. [*Edinburgh* 1894.]

<div align="right">The Author.</div>

Hayter (H. H.) Victorian Year-Book. 1893. Vol. I. 8vo. *Melbourne* 1893.   The Author.

Johnston (R. M.) Handbook of Tasmania for the Year 1893. 8vo. *Hobart* 1894.   Government Statistician, Hobart.

Johnston-Lavis (H. J.) The Ejected Blocks of Monte Somma. Part 1. Stratified Limestones. 8vo. *Edinburgh* 1893. [And two other Excerpts.]   The Author.

Kelvin (Lord), P.R.S. Popular Lectures and Addresses. Vol. II. 8vo. *London* 1894.   The Author.

<div align="right">2 E 2</div>

Marsh (O. C.) Restoration of Comptosaurus. 8vo. [*New Haven*] 1894. The Author.

Praschkauer (M.) Ein Abriss ueber das Englische Arbitrations— (Schiedsrichter) Wesen. 8vo. *London* 1894. The Author.

Schwalbe (B.) Über wissenschaftliche Fachlitteratur und die Mittel dieselbe allgemein und leicht zugänglich zu machen. 8vo. *Berlin* [1894]. The Author.

White (W. H.), F.R.S. A Manual of Naval Architecture. Third edition. 8vo. *London* 1894. The Author.

Williamson (B.), F.R.S. Introduction to the Mathematical Theory of the Stress and Strain of Elastic Solids. 8vo. *London* 1894. The Author.

Circular Case for a Rumford Medal, made out of the wood from an ash tree, until lately growing in front of Count Rumford's house, North Woburn, Massachusetts, and contemporary with him.
Rumford Historical Association, North Woburn, Mass., through Dr. Ephraim Cutter.

April 26, 1894.

The LORD KELVIN, D.C.L., LL.D., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

Pursuant to notice, Professor Henri Ernest Baillon, Professor Henri Poincaré, and Professor Eduard Suess were balloted for and elected Foreign Members of the Society.

The following Papers were read :—

I. "On the Specific Heats of Gases at Constant Volume. Part II. Carbon Dioxide." By J. JOLY, M.A., Sc.D., F.R.S. Received March 9, 1894.

(Abstract.)

In the former experiments on this gas, recorded in the first part of this research,[*] the highest absolute density at which the specific heat was determined was 0·0378. In the present observations the deter-

---

[*] "On the Specific Heats of Gases at Constant Volume," Part I, 'Phil. Trans., A, vol. 182, 1891, pp. 73–117.

minations of specific heat have been carried to densities at which the substance was partly in the liquid state at the lower limit of temperature of the experiments. Observations dealing with true specific heat, uncomplicated by the presence of thermal effects due to the presence of liquid, are limited by the density 0·1444. At this density the mean specific heat over the range, 12° C. to 100° C., is 0·2035.

The following table contains a summary of the mean results of the experiments in which no liquid is present at the initial temperature. The range of these experiments lies between air temperature (12° to 16°) and steam temperature —

Specific heat.	Density.	Specific heat.	Density.
0·1714	0·0377	0·1942	0·1177
0·1759	0·0498	0·1948	0·1178
0·1778	0·0554	0·1963	0·1288
0·1794	0·0604	0·1994	0·1322
0·1799	0·0685	0·1992	0·1323
0·1839	0·0771	0·2025	0·1443
0·1869	0·0891	0·2030	0·1444
0·1895	0·1016	—	—

These observations, combined with those contained in Part I. (*loc. cit.*), afford a well defined line, which rises slowly at the higher densities, turning away from the axis of density.

According to an empirical equation to this line, the specific heat of carbon dioxide at constant volume is given in terms of its variation with density ρ, as follows :—

$$C_V = 0 \cdot 1650 + 0 \cdot 2125 \rho + 0 \cdot 3400 \rho^2.$$

This is in fair agreement with the linear equation deduced in Part I from the limited number of experiments at low densities therein contained :—

$$C_V = 0 \cdot 16577 + 0 \cdot 2064 \rho.$$

In these experiments a spherical vessel of copper was used to hold the gas, having a voluminal capacity of about 86 c.c., a mass of 137 grams, and an estimated resistance to bursting of 300 atmos. This, as in the former experiments, was equilibrated against a similar vessel in a differential steam calorimeter. These vessels produced each a precipitation, due to its own calorific capacity of 2·1 grams of steam. It was found, however, that closely agreeing results (to 1 per cent. about) were obtained when the precipitation due to the gas fell to as little as 0·15 gram.

II. "On the Specific Heats of Gases at Constant Volume. Part III. The Specific Heat of Carbon Dioxide as a Function of Temperature." By J. JOLY, M.A., Sc.D., F.R.S. Received March 9, 1894.

(Abstract.)

In order to investigate the question of the variation of the specific heat of carbon dioxide with temperature, a steam calorimeter was constructed having double walls of thin brass, between which the vapour of a liquid boiling under atmospheric pressure could be circulated. The vessels used in the experiments were hung in the closed inner chamber. Into this chamber steam could be admitted after the temperature had become stationary and the same as that of the jacketting vapour. In this way the initial temperature could be varied.

Experiments at various densities and over four intervals of temperature were carried out. The densities chosen were 0·0456; 0·0800; 0·1240; 0·1800, and 0·1973. The intervals of temperature over which the gas at each density was investigated were: air temperature to 100°; 35° C. (boiling point of ether) to 100°; 56° (boiling point of acetone) to 100°, and 78° (boiling point of ethyl alcohol) to 100°.

The results are plotted on 5 equi-density lines, and it was found most intelligible to plot the precipitation due to the calorific capacity of the gas between t_1 and 100° against the initial temperature t_1 in each case. If the initial temperatures are measured as abscissæ, starting from 0° C. at the origin, and the precipitations are set off as ordinates, the 5 equi-density lines so determined slope downwards to the right (the slope increasing with the density), passing, necessarily, through the point 100° C. on the axis of temperature in each case. If the specific heat is invariable these are right lines. This proves to be sensibly the case for the lines $\rho = 0·0456$ and $\rho = 0·0800$; those of lowest density.

The next line, 0·124, is nearly rectilinear over the higher ranges, but pursued from right to left it rises markedly at the lower temperatures; thus indicating that the specific heat at constant volume falls in value with increasing temperature. The line $\rho = 0·1800$ and the one close above it, $\rho = 0·1973$, show this variation very markedly. Their variation below the critical temperature is complicated by the presence of liquid.

The following table contains the principal results. The column *headed w* contains the weight in grams of the precipitation due to the

calorific capacity of the gas between the initial temperature and 100° C.

Density.	*w*.	Specific Heat.	Initial temperature.
0·1973	0·8701	0·3046*	12·79
	0·4592	0·2130	34·02
	0·1459	0·2035	77·84
0·1800	0·7129	0·2731†	13·12
	0·4008	0·2061	35·17
	0·2693	0·2044	56·13
	0·1321	0·2022	77·87
0·1240	0·4150	0·2154‡	6·39
	0·2591	0·1938	35·05
	0·1716	0·1912	56·49
	0·0861	0·1916	78·18
0·0800	0·2235	0·1844	8·03
	0·1559	0·1837	35·70
	0·1042	0·1817	56·79
	0·0538	0·1863(?)	78·14
0·0456	0·1154	0·1774	11·35
	0·0837	0·1754(?)	35·06
	0·0567	0·1773	56·68
	0·0300	0·1863(?)	78·14

The following empirical equation expresses the line $\rho = 0.124$ calculated into a line of variation of specific-heat with temperature:—

$$C_V = a + 2b(100-t) + 3c(100-t)^2,$$

where t is the initial temperature of the experiment in centigrade degrees;

$$a = 0.19020000.$$
$$b = 0.00006750.$$
$$c = 0.00000182.$$

Theoretical considerations led Rankine and others to predict a decrement of the specific heat of a gas at constant volume with rise of temperature. The characteristic-equation of carbon dioxide does not seem to have been given as yet in a satisfactory form for application to the higher pressures. Probably on this account only an approximate agreement is found to exist between the numerical amount of the decrement predicted and that observed experimentally at the higher densities. At the lower densities the sensible absence of variation with temperature over the range of the observations is in perfect agreement with the theoretical numbers.

* Liquid present up to 21°, *q. p.*
† „ „ 18°, *q. p.*
‡ „ „ 8°, *q. p.*

III. "A Contribution to the Study of the Yellow Colouring Matter of the Urine." By ARCHIBALD E. GARROD, M.A., M.D. Oxon., F.R.C.P. Communicated by Sir ALFRED B. GARROD, M.D., F.R.S. Received February 5, 1894.

The uncertainty which still surrounds the origin of a phenomenon so familiar as the yellow coloration of the urine bears eloquent testimony to the difficulties which beset the investigation, by ordinary chemical methods, of such substances as the urinary pigments, and to the importance of the part which the spectroscope has played in the acquisition of such knowledge of them as we possess.

Indeed, our acquaintance with the individual pigments is proportional to the distinctive character of their absorption spectra, rather than to the time which has elapsed since they first attracted attention; and in not a few modern works doubt is thrown upon the very existence of a distinct yellow pigment, having negative spectroscopic properties, but to which normal urine owes its characteristic tint, the chief part in the coloration of the excretion being assigned to urobilin.

In this connexion the spectro-photometric researches of Vierordt[*] are of much importance, for they appear to show conclusively that more than one pigment is present in normal urine. Vierordt found that with different specimens of the urine of a single healthy individual, examined at considerable intervals, the extinction coefficients for different parts of the spectrum exhibited relative as well as positive differences.

The variations of positive value are of course dependent upon the depth of colour of the specimen, but the relative variations can only be explained by the presence, in varying proportions, of two or more distinct pigments.

It must not, however, be forgotten that, as Vierordt himself points out, pigments which yield definite absorption bands may influence the extinction coefficients, even when present in such small quantities that their bands are not visible as such; and it can be shown that at least three colouring matters, apart from a yellow pigment, may be present in any given specimen of the urine of a healthy individual, which may, nevertheless, exhibit no obvious selective absorption.

Of these pigments, urobilin is certainly one, and when not seen on direct examination of the untreated normal urine, its band not infrequently appears on standing, or on the addition of a mineral acid.

Yet the quantity present is at best extremely minute, and wholly

* 'Die Quantitative Spectralanalyse.' Tübingen, 1876, p. 78.

inadequate to account for the coloration, and I am therefore convinced that the statement that urobilin is the chief colouring matter of normal urine is entirely incorrect. Indeed, as far as normal urine is concerned, urobilin can hardly be reckoned as one of its colouring matters at all, for even a very faintly tinted solution of this pigment yields a well-defined absorption band, far darker than is ever seen in normal urine. In some morbid urines, on the other hand, it affects the colour profoundly.

The second pigment referred to is hæmatoporphyrin, which, as I have elsewhere shown,[*] can usually be detected by appropriate means even in normal urine; but here, again, the amount present is so infinitesimal that it can have no appreciable effect upon the colour.

The occasional deposition of pink urate sediments, apart from any noticeable deviation from perfect health, shows that uroerythrin must also be reckoned among the pigments of normal urine; and if further confirmation is needed, it is obtained, as Riva[†] and Zoja have shown, by the examination of the extracts obtained by shaking specimens of urine with amylic alcohol.

Since, however, the above-mentioned pigments, with the possible exception of uroerythrin, can have no material influence upon the colour of normal urine, we are driven to the conclusion that there must exist in the urine another much more abundant colouring matter, of a yellow tint, which even in concentrated solution yields no absorption bands, or that the colour is due to the presence of more than one such substance.

There are not wanting records of investigations directed to the isolation of such a pigment, or mixture of pigments, and products have been obtained by several observers, which they have looked upon as the substance in question, but the various products have differed in their properties, and no one of them has met with general acceptance.

The literature of the subject will be found admirably epitomized in papers by Thudichum[‡] and Schunck,[§] published in 1864 and 1867 respectively, and to these epitomes there remains little to be added, seeing that during the twenty-seven years which have since elapsed, no fresh observer has, as far as I am aware, published any investigations upon the subject.

Referring my readers to these epitomes for records of the earlier work of Proust, Berzelius, Lehmann, Harley, and others, I only propose to allude here to the results obtained by Tichborne, Thudichum, and Schunck.

---

[*] ' Journal of Physiology,' 1892, vol. 13, p. 619.

[†] ' Gazzetta Medica di Torino,' 1892, vol. 43, p. 925.

[‡] ' British Med. Journal,' 1864, vol. 2, p. 509.

[§] ' Roy. Soc. Proc.,' 1867, vol. 16, p. 85.

C. Tichborne* (1862) threw down most of the colouring matter of a large quantity of concentrated urine upon a basic copper precipitate, and extracted the pigment from the precipitate by means of cold dilute sulphuric acid and alcohol.

In this way he obtained a solution which, on evaporation, left a brown residue, very hygroscopic and smelling of stale urine, solutions of which yielded, according to the degree of concentration, the various tints of normal urines.

The pigment was soluble to almost any extent in water, was insoluble in ether, sparingly soluble in absolute alcohol, and more readily in rectified spirit. It was precipitated from solution by basic lead acetate.

The results of elementary analysis led Tichborne to think that it was derived from hippuric acid by the subtraction of water, the percentage composition obtained being C, 67·80; H, 4·23; N, 8·56; O, 19·41.

It is extremely doubtful whether combustion analyses of such substances are calculated to materially advance our knowledge, in the absence of any of the ordinary guarantees of the purity of the substance analysed; and so simple a process as that employed by Tichborne could only be expected to yield a product of a moderate degree of purity.

Thudichum† (1864) obtained from normal urine by a variety of processes a substance to which he gave the name of urochrome, and his researches which have extended over a long period form the most elaborate contribution yet made to the subject.

In the second edition of his work on the urine,‡ in which his later researches are embodied, he gives four methods for the isolation of urochrome in which phosphomolybdic acid and the neutral and basic lead acetates are employed as precipitants, and sulphuric acid, sulphuretted hydrogen, &c., for the extraction of the pigment from the precipitates. Great pains were taken to obtain the pigment in the highest attainable degree of purity.

Thudichum describes urochrome as forming yellow crusts when its solutions are evaporated, as dissolving very readily in water, fairly readily in ether, and least easily in alcohol. It was precipitated from its solutions by lead acetate, silver nitrate, acetate and nitrate of mercury, &c.

On heating with mineral acids the aqueous solution became red, and resinous flakes were thrown down from which three definite substances could be obtained, which were minutely studied, and subjected to ultimate analysis. These substances were a red pigment,

* ' Chemical News,' 1862, vol. 5, p. 171.

† *Loc. cit.*

‡ ' Pathology of the Urine,' 2nd Edit., 1877, p. 217.

soluble in ether, with a port wine colour, and showing an absorption band to the more refrangible side of D (omicholic acid), a portion soluble in alcohol, showing a band extending from E to beyond F (uropittine), and a residue scarcely soluble in water or alcohol, but readily dissolved by alkalies (uromelanine).

Thudichum assigns to urochrome a faint absorption band at F, and was led to regard the pigment as a feeble alkaloid, on account of its precipitation by phosphomolybdic acid.

Schunck[*] (1867) employed the acetates of lead as precipitants, and extracted the colouring matter with cold sulphuric acid or sulphuretted hydrogen. He came to the conclusion that the urine owes its colour to two distinct yellow pigments, one soluble and the other insoluble in ether.

The pigment soluble in ether (urian) yielded, on heating with mineral acids, a brown resinous substance, readily soluble in alcohol (uroretine), whereas the pigment insoluble in ether (urianin) yielded a brown flocculent substance scarcely soluble in alcohol (uro-melanine). He made numerous combustion analyses of these products, and his results differed widely from those of Tichborne, especially in the much smaller percentage of carbon found. For urian, the pigment soluble in ether, Schunck obtained the percentage composition C, 51·23; H, 5·38; N, 1·26; O, 42·13. Whereas urianin gave C, 46·44; H, 5·66; N, 3·16; O, 44·74.

In more recent years, Thudichum has on various occasions upheld the claims of urochrome to be regarded as a definite chemical entity,[†] in reply to the criticisms of Maly[‡] and others.

Dr. Lewis Jones, who, some years ago, made some investigations on this subject, has favoured me with an account of his results, which were never published. He arrived at the conviction that the yellow colour of urine could not be due to urobilin, which, in solution, has a redder colour than urine. Moreover, the yellow pigment is insoluble in chloroform, in which urobilin dissolves freely. Urobilin, even in very dilute solution, has a very distinct absorption band at F, whereas normal urine shows no band at F unless viewed in deep layers, and then shows only a diffused obscuration about the region of the F line, quite unlike the sharp band of urobilin.

He found that an extract obtained by the lead acetate method, evaporated *in vacuo*, with proper precautions, yielded a yellowish crust, from which chloroform dissolved out any traces of urobilin. The remainder, when dissolved in water, reproduced the colour of the original urine when diluted to the same bulk. From normal urine the amount of urobilin obtained was very minute; more could be

---

[*] *Loc. cit.*
[†] ' Journal Chem. Soc.,' vol. 18, 1875, p. 392.
[‡] ' Ann. der Chem. und Pharm.,' vol. 163, p. 90.

extracted from the highly-coloured urine of febrile patients, but in neither case does he consider that the quantity present suffices to materially affect the colour of the urine when diluted to the original bulk.

He adds: "I am disposed to regard the colour of urine as being due to the presence of a yellow body which, for the present, may be called urochrome, and, without positively denying the presence of traces of urobilin in normal urine, I consider that the amount which occurs in ordinary specimens is far too minute to affect the colour, whilst even in febrile urine the colour is only modified a little by the presence of urobilin."

The present writer was led to approach this difficult problem by the study of the coloration of uric acid sediments in urine, in which it became obvious that the yellow pigment played an important part. Attempts were therefore made to extract this pigment for purposes of further investigation, by a process which should differ from those hitherto employed in the following important respects :—

1. That, if possible, the recognised urinary pigments, and especially urobilin should be got rid of at the outset.
2. That the employment of powerful reagents, and especially of mineral acids, should be, as far as possible, avoided.
3. That the colouring matter should not be precipitated by lead acetate or other metallic compounds, and afterwards extracted from the precipitate.

After many attempts and repeated failures, a method was devised which, to a great extent, fulfils the above conditions, the essential parts of the process being as follows :—

1. Saturation of the urine with pure ammonium sulphate and filtration.
2. Extraction, from the filtrate, with ethylic alcohol, which separates out from the saturated liquid, and carries most of the colouring matter with it.
3. Evaporation, and solution of the residue in absolute alcohol.
4. Precipitation of the pigment from its alcoholic solution by excess of ether.

For purposes of more detailed description, it will be convenient to divide the process into the above four stages.

Stage I.—A pint or two of concentrated normal urine is saturated with pure ammonium sulphate, solution being aided by gentle warmth, and is then passed through a filter.

The filtrate is clear and has a pure golden colour, somewhat paler *than* that of the original urine.

The precipitate, which varies in tint from brown to pink, contains

any urobilin that may be present, as has been shown by G. Hoppe Seyler,* who makes saturation with ammonium sulphate the starting point of his process for the quantitative estimation of that substance.

Acidulated alcoholic extracts from the precipitate usually show a faint urobilin band, and sometimes still fainter bands of acid hæmatoporphyrin. Unusually pink precipitates will be turned green by alkalies, which shows that they contain uroerythrin.

If the precipitate be washed with water a yellow solution is obtained, which is found to contain some of the yellow pigment precipitated by the saturation.

Lastly, in addition to mucus, there may remain upon the filter paper a black residue, insoluble in water, alcohol, and dilute acids, but slightly soluble in soda, potash, or strong ammonia, which is an impurity derived from the ammonium sulphate.

A morbid urine, highly coloured with urobilin, yields a yellow filtrate, like that obtained with normal urine, which shows no urobilin band. I have reason to think that there is no such complete removal of hæmatoporphyrin, but any traces of this pigment which may exist in the filtrate are removed at a later stage.

Stage II.—To the saturated clear yellow filtrate absolute alcohol is next added, which throws down some of the ammonium sulphate, and after a small quantity has been added, quickly separates and collects upon the surface as a clear layer, carrying with it the bulk of the yellow pigment.

The alcohol is then separated off from the partially decolorised urine, from which a further supply of pigment can be obtained by a fresh addition of alcohol. By repeated extraction the pigment may be almost completely removed, but the result does not repay the expenditure of alcohol entailed. If rectified spirit be used instead of absolute alcohol, a considerably larger quantity is required to produce satisfactory separation.

The alcoholic extract thus obtained is next poured into a considerable bulk of distilled water, and the alcohol is again caused to separate out by once more saturating with ammonium sulphate, with the aid of gentle warmth. This washing process, which entails some loss of pigment, is of much importance, as by this means urea and other crystalline impurities are to a large extent got rid of; and its omission is apt to give rise to trouble at a later stage.

The golden orange-coloured extract thus obtained is inflammable, but will not mix with chloroform, as it still contains water and ammonium sulphate. It is therefore poured upon some fresh ammonium sulphate and gently warmed, when two layers will form, the lower of which is almost colourless, and represents much of the water pre-

* ' Virchow's Archiv,' vol. 124, 1891, p. 80.

viously contained in the extract, the bulk of the dissolved ammonium sulphate being separated with it.

Stage III.—The lower layer having been removed, the alcoholic extract is now evaporated to dryness over a water bath, a few drops of ammonia being added from time to time so as to maintain an alkaline reaction.

This precaution is rendered necessary by the presence in the extract of a considerable quantity of indoxyl sulphate, which is otherwise apt to be decomposed during the evaporation, with the formation of indigo pigments.   '

Such decomposition cannot take place if the liquid be kept alkaline, for, as Baumann showed, the indoxyl sulphates may be boiled with caustic alkalies without undergoing change ; and, far from producing any alteration in the yellow pigment, the ammonia tends to preserve it from changes to which it is otherwise liable.

A brown residue remains after the evaporation is complete, which has a treacly consistence, but solidifies on cooling.   This residue, which emits a powerful urinous odour, and contains some ammonium sulphate, is washed once or twice with acetic ether, which removes the bulk of the indoxyl sulphate, and comparatively little of the yellow pigment.   It is then transferred to a stoppered bottle and allowed to soak for some hours in absolute alcohol.   On filtering a beautiful orange-coloured alcoholic solution is obtained, but some of the pigment escapes solution and may be in part removed by a second soaking in fresh alcohol.

Water dissolves the undissolved residue readily and completely, and if the aqueous solution so obtained is treated like the original urine by saturation with ammonium sulphate and extraction with alcohol, a further supply of absolute alcoholic solution may be obtained from it, which has the advantage of being free from indoxyl sulphate.

It is probable that some of the pigment has · undergone a slight change which renders it very sparingly soluble in alcohol.

Stage IV.—The alcoholic solution, which, when treated in the cold with hydrochloric acid and a trace of chloride of lime, still yields an indigo reaction, is next concentrated, if necessary, until it has a · rich orange colour.   It is then poured into rather more than its own bulk of ether, whereupon much of the pigment is precipitated in an amorphous state, and may be collected upon a filter which has been first moistened with pure ether to ensure rapid filtration.

The presence of a very little water prevents the precipitation, a few drops of a very concentrated aqueous solution separating out and passing through the filter.

If the various stages of the process have been carefully followed, *and especially* if the second separation of the alcoholic extract from

distilled water has been carried out, the filter paper will merely be coated with an amorphous brown film, and there will be no appreciable deposit of crystalline impurities. The filtrate of ether and alcohol will have a yellow colour, as it is able to hold a considerable quantity of pigment in solution.

The filter paper, to which the pigment clings tenaciously, is allowed to dry and is then soaked for a time in chloroform which remains untinted, and afterwards in absolute alcohol. The alcohol becomes coloured by the pigment, but does not dissolve it nearly so readily as before.

The paper is then allowed to soak for an hour or so in distilled water, by which means a clear orange-coloured or yellow aqueous solution is obtained, which should yield no indigo reaction, and which contains the pigment in a condition approaching to purity, although it is certainly not entirely pure. I believe, however, that no pigment other than the yellow one is present, and the absence of those which show absorption bands can be definitely established.

When it is treated with sodium hypobromite, a little nitrogen is evolved, the freedom from urea being in proportion to the amount of washing or soaking in alcohol that the brown precipitate has received. If only slightly washed, 1 c.c. of a concentrated solution tested by means of Southall's apparatus, may give off nitrogen equivalent to as much as 0·003 gram of urea, but if the washing has been more thorough, the amount evolved is too small to be measured.

Seeing how soluble urea is in alcohol and in water, whilst it is almost insoluble in ether, it is only to be expected that this substance should constitute the chief impurity in the specimens.

When the residue obtained by evaporation of the aqueous solution is burnt on a platinum dish, it yields a very bulky mass of carbon, and ultimately a trace of colourless ash, varying in quantity, which is readily soluble in water, contains no appreciable amount of carbonate, and apparently consists of sodium phosphate.*

* *May 9th*, 1894.—It has been suggested that the yellow pigment may contain some, at least, of the iron which is present in urine, but although I cannot state that the product obtained by the above process is *absolutely* free from iron, the amount of that element contained in it is, at most, exceedingly minute. After the combustion of such small quantities as 1 or 2 cgrm. of the dry pigment, the sulphocyanide test gave negative results, provided that iron-free reagents, and filter-papers which had been extracted with hydrochloric acid, were employed in the process ; but with as much as 6 cgrm. a just perceptible tint was obtained, in no way comparable with that yielded by a fiftieth part of that weight of hæmoglobin. I am, therefore, inclined to look upon this minute trace of iron as an accidental impurity, probably derived from the urine, rather than as a constituent of the yellow pigment.

When heated with potassium hydrate the yellow pigment was found to give off ammonia freely.

The final product represents but a small part of the yellow pigment present in the original specimen of urine, conspicuous loss being entailed in the washing of the alcoholic extract, the washing with acetic ether, and especially in the precipitation with ether.

I have not made any ultimate analysis of the product, since such an analysis would have little value without further guarantees of the purity of the product, and such guarantees could hardly be obtained in the case of a colloid substance such as this pigment is. A long series of combustion analyses, if they yielded uniform results, would doubtless go far towards establishing its percentage composition, but in order to obtain the material required for such a series, very large amounts of urine would have to be dealt with, and a correspondingly large consumption of the materials employed in the extraction of the pigment would be involved.

Properties of the Solid Pigment.

In the solid state the product obtained by the above process was completely amorphous and brown in colour. It was so hygroscopic that it could not be completely dried in air, but in the exsiccator, over sulphuric acid, it lost its viscosity, and became quite hard.

It dissolved in water with the greatest facility, readily in rectified spirit, and much less readily in absolute alcohol. Acetic ether, amylic alcohol, and acetone dissolved the pigment sparingly.

The solubility of the product in alcohol appeared to undergo a progressive diminution, through the successive stages of extraction, and after each evaporation of an alcoholic solution some of the pigment was apt to escape re-solution in alcohol.

In pure ether, chloroform, and benzene it was quite insoluble, but mixtures of ether or chloroform with alcohol dissolved it to some extent. In its purest state the pigment was practically odourless when cold, but on the water-bath it softened and emitted a slight urinous odour.

Properties of Solutions of the Pigment.

The solutions of the pigment in alcohol or in water reproduced on dilution the various shades of yellow and orange colour of normal urines. On concentration they passed through various shades of orange to a rich, warm brown.

Blue litmus paper dipped into the solutions was slightly reddened, and red litmus took a faint blue tint.

When the solutions were placed before the spectroscope they showed no absorption bands, even on the addition of an acid. The blue end of the spectrum was absorbed, and the absorption faded *away so gradually* towards the yellow, that even with concentrated solu-

tions it was not possible to assign to it even an approximate limit. There was no increase of the absorption in the position of the urobilin band.

Treatment with zinc chloride and ammonia did not produce any fluorescence.

The alcoholic solutions always showed the same rich yellow or orange tint, and could be kept for a long time without undergoing any appreciable change; but aqueous solutions kept in stoppered bottles tended to assume a brown tint on standing, even when dilute, and this change was precipitated by evaporation or warmth. In this respect my product behaved just like urochrome.

The tendency of the aqueous solutions to undergo this change could be restrained by the addition of a little ammonia.

Alkalies did not appreciably alter the tint of dilute solutions, but. more concentrated ones were slightly browner when alkaline than in the neutral condition.

Small additions of mineral acid produced.no immediate change, but larger quantities quickly changed the colour to a reddish-brown.

Solutions of the pigment were decolorised by nascent hydrogen produced by the action of hydrochloric acid upon zinc. This is only to be expected, seeing that it is a known fact that the urine is itself decolorised by similar treatment.* The destroyed colour was not restored by hydrogen peroxide.

Action of Mineral Acids upon the Pigment.

Solutions of the yellow pigment when warmed with nitric acid remained clear, but took a distinctly brighter yellow tint. On the addition of ammonia to alkalinity the yellow colour changed to a rich orange, the changes of tint being exactly similar to those which con-stitute the xanthoproteic reaction. This reaction seemed to be due to a change in the pigment as a whole, and not to any traces of impurity present.

Heated over the water bath with the addition of sulphuric or hydrochloric acid, the changes observed were uniform with all speci-mens of the indigo-free pigment which were subjected to this treatment, and were the same whichever of the two acids was employed.

The colour of the liquid quickly changed to reddish-brown, and on evaporation to dryness a nearly black residue was left. This residue, when treated with water, yields an orange-coloured solution, resem-bling the original liquid in colour, but darker in tint. This aqueous extract left on evaporation a brown residue, which was scarcely soluble in alcohol, but which communicated a yellow colour to chloroform.

* Salkowski und Leube, ' Die Lehre vom Harn,' 1882, p. 14.

From the remainder of the original residue alcohol extracted more pigment, and hot alcohol more still, the liquid assuming a sepia tint, and showing no absorption bands. The hot alcoholic solution deposited, on cooling, a dark, pulverulent sediment, which, examined microscopically, was found to be amorphous. A black residue still remained which was insoluble in water, alcohol, and dilute acids, was scarcely soluble in amylic alcohol, but was readily dissolved by strong ammonia (the uromelanine of Thudichum). The alkaline solution gave no absorption bands.

After extraction with water the original residue communicated a yellow colour to ether, but no substance resembling the omicholic acid of Thudichum (which is readily soluble in ether with a fine red colour) was obtained.

Precipitants of the Yellow Pigment.

In its behaviour towards metallic salts the pigment obtained by my process exhibited the closest resemblance to the urochrome of Thudichum.

The solutions were almost decolorised by the acetates of lead, by nitrate of silver, and by phosphotungstic and phosphomolybdic acids, which all threw down precipitates containing the bulk of the pigment.

Mercuric acetate decolorised the solutions completely, a yellow precipitate being formed, from which the colouring matter could be readily extracted with alcohol acidulated with hydrochloric acid, but apparently not without some change, evidenced by its reddish-brown colour.

Mercurous acetate had not the power of throwing down the pigment from its solutions.

Behaviour of the Pigment towards Uric Acid.

If to a solution of colourless urate, obtained from snake's excrement, some of the yellow pigment was added, and if the conditions of the experiment were so adjusted that crystals of uric acid are slowly deposited from the solution, these crystals resembled those which compose the yellow or brown variety of uric acid sand, and had, moreover, the ordinary urinary forms, the familiar whetstone shape preponderating. I have, indeed, specimens of crystals so obtained which are quite indistinguishable from those of the natural urinary sediments.

This experiment is difficult to carry out satisfactorily, chiefly owing to the instability of the isolated pigment. If the crystals are too quickly deposited they have the whetstone form, but are only

faintly tinted. If acid is added they have a brown colour like that of crystals thrown down on the addition of acid to urine.

The converse experiment to this was performed some years ago by Ord,[*] who showed that, on repeatedly redissolving and reprecipitating urinary uric acid, the crystals lost their colour, and, at the same time, tended to assume the tabular forms of those of pure uric acid.

The above result lends strong support to the view that the pigment is isolated by the alcohol process in the form in which it actually exists in the fresh urine, and confirms the statement that it plays an important part in determining the forms which the crystals assume.[*]

Another fact which is demonstrated by this experiment is that the yellow pigment is one of those which colours the urinary crystals, although it does not stand alone in this respect. I do not, however, propose to enter further into this subject here, as I hope to deal with it at length in a separate paper, but I may mention that crystals of uric acid which are deposited from a solution of urobilin are colourless and exhibit no modification of form, resembling, in every respect, those thrown down from pure aqueous solutions of urates.

Summary and Conclusions.

There cannot, I think, be any doubt that the substance isolated from the normal urine by the process here described is that to which its colour is almost entirely, if not entirely, due, and, since solutions of this substance do not fluoresce with zinc chloride and ammonia, show no absorption bands, and cannot be got to show a urobilin band by any process to which it was subjected, it follows that urobilin is not the chief colouring matter of normal urine. Moreover, there is every reason to believe that the product obtained has not undergone any notable change in the process of extraction, although its solubility in various media appears to be somewhat impaired.

The question whether the yellow colouring matter so obtained is a definite chemical entity is one to which it is very difficult to give a conclusive answer, chiefly on account of its physical properties. However, the uniform course of events observed on each of the many occasions on which the alcohol and ether process was carried out, strongly suggested that the product was a definite compound.

This view also received support from its behaviour towards its solvents and its precipitation by ether, as well as by its effect upon uric acid crystals, which is hardly what might be expected from a mixture of pigmentary substances.

The only fact with which I am acquainted which appears to be opposed to this idea is the impossibility of completely decolorising its solutions by certain metallic precipitants, which throw down the

---

[*] "The Influence of Colloids upon Crystalline Form and Cohesion," 1879, p. 52.

great bulk of the pigment; but, since we are ignorant of the form in which the pigment exists in such precipitates, *i.e.*, whether it is in actual chemical combination with the precipitant, this objection does not appear to be insuperable, especially as other pigments, which are certainly definite compounds, appear to behave in a similar way.

There can, I think, be little doubt that the same substance formed the basis of the products obtained by Thudichum, Tichborne, Schunck, and myself, such differences as were observed being due to varying degrees of purity, and probably to changes produced in the pigment by the various methods of extraction employed.

The most important respects in which my product differed from the urochrome of Thudichum were its behaviour with ether and when heated with mineral acids.

The fact that ether, when shaken with normal urine, does not acquire any yellow tint suggests, but does not prove, that, in its original condition, the yellow pigment is insoluble in ether, and at no stage of my process is the product soluble in that medium. Urochrome, on the other hand, is described by Thudichum as being more readily soluble in ether than in alcohol. Again, a portion of Schunck's product (urian) was also soluble in ether.

I have myself found that the pigment obtained from urine by saturation with baryta, precipitation with the acetates of lead, and extraction of the precipitate with cold dilute sulphuric acid, followed by immediate neutralisation with ammonia, is to some extent soluble both in ether and in chloroform, and can only attribute this difference to a change produced by the process of extraction employed.

When acted upon by hydrochloric or sulphuric acid upon a water bath, my product behaved more like those of Schunck than like urochrome. The chief difference from Thudichum's results was that no portion of the residue was soluble in ether with a red colour. I should, however, mention that I have repeatedly obtained a substance yielding a rich red ethereal solution, when the specimens treated had not been freed from indoxyl sulphate, but never when this impurity had been got rid of.

To the difficult questions connected with the origin and formation, in considerable quantities, of a pigment, such as is here described, the source whence it is derived, and the manner in which it enters the urine, of which it is a constant constituent, it is, at present, impossible to venture even a hypothetical answer; and we may well content ourselves for some time to come with the attempt to establish upon a firm basis the contention that the yellow colour of urine is not due to any of the band-yielding pigments, but to a distinct yellow colouring matter, of negative spectroscopic properties, which may be judged from its reactions to be a definite chemical entity. For the designa-

tion of this substance the name "Urochrome," assigned to it by Thudichum, appears eminently suitable.

The only points hitherto brought out which afford any clue to the chemical relationships of this pigment are the resemblance of the products of its decomposition to the humous substances described by Udránszky,[*] and the fact that it yields, when heated with nitric acid, a colour reaction which is indistinguishable from the xanthoproteic reaction, suggesting a relationship to the members of the aromatic series.

Udránszky classes Thudichum's uromelanine and the other products of the decomposition of urochrome as humous substances, and suggests as a possibility that the conversion of carbohydrates into such substances begins even within the body, and so may contribute to the yellow coloration of urine.

Certainly uromelanine has, as might be expected, certain obvious resemblances to the products which Udránszky obtained by the action of acids upon urine, and Thudichum long ago described how it might be prepared directly from urine by similar means. On the other hand, even if it be granted that the yellow pigment does yield humous substances on decomposition, any argument based upon this may well be regarded as open to the objection of explaining *ignotum per ignotius.*

IV. " Some Points in the Histology of the Nervous System of the Embryonic Lobster." By EDGAR J. ALLEN, B.Sc. (London). Communicated by Professor W. F. R. WELDON, F.R.S. Received February 10, 1894.

Tho following observations have been made on late embryos of the common lobster (*Homarus vulgaris*) by means of Ehrlich's methylene blue method, as modified by Biedermann[†] and Apáthy.[‡] The results to be recorded in the present communication apply chiefly to the thoracic ganglia, which in the embryo are fused into one mass.

The nerve elements, which have stained, may be divided into three main groups :—

I. Elements of which both the cell and the fibre lie entirely in the ganglionic chain, and which must be supposed to serve the purpose of co-ordinating the action of its various parts.

* ' Zeitschrift. f. Physiol. Chemie,' vol. 11, 1887, p. 537, and vol. 12, 1888, p. 33.

† Biedermann, " Ueber den Ursprung und die Endigungsweise der Nerven in den Ganglien wirbelloser Thiere," ' Jena. Zeitschr.,' vol. 25, 1891.

‡ Apáthy, " Erfahrung in der Behandlung des Nervensystems für histologische Zwecke," I, Methylenblau. ' Zeitschr. Wiss. Mikr.,' vol. 9, 189

œs., œsophagus; *tr. br.*, transverse bridge behind œsophagus; *gan. c.*, central mass of ganglion cells *musc.*, nerve ending on muscle; *Ant. II*, ganglion of Antenna II; *Th. I—XI*, thoracic ganglia *I—VI* form anterior thoracic ganglion of adul ; *A—J*, individual nerve elements. For descri tion of each, see text.

II. Elements which consist of a ganglion cell in the cord and a fibre which runs out at a lateral nerve root. Some, at least, of these elements, possibly all, are connected with muscles, and are motor elements.

III. Elements which consist of a cell lying *outside* the central ganglionic chain, and a fibre running from it to a ganglion. These must be regarded as sensory elements.

I. Elements of the first group, co-ordinating elements, are of four kinds.

A. Elements made up of a cell in the brain or one of the ganglia, and a fibre which runs posteriorly to the end of the cord, giving off collateral branches to the neuropile in each ganglion through which it passes. For reasons to be explained, these elements must be regarded as placed temporarily in the groups of co-ordinating elements. It may be necessary to place them in a new group by themselves.

Two kinds of A elements may be distinguished :—

(*a*.) Those which decussate with the corresponding element of the opposite side.

(*b*.) Those which pass down on the same side of the cord as that on which the cell lies.

The elements A (*a*) inserted in the ganglion of Antenna II and Thorax II (fig. 1) may be taken as typical of the fibres which decussate. The cell lies in the lateral mass of ganglion cells, and the fibre gives off lateral branches to the neuropile before crossing to the other side. After the decussation has taken place the fibre turns backwards, and runs down the ganglionic chain, giving off collateral branches to the neuropile of each ganglion through which it passes. The fibre A (*a*) Thorax II, together with a corresponding fibre in Thorax I, have been traced as far as the last abdominal ganglion, but no definite ending has been made out. A (*a*), Antenna II, was only actually traced to Abdomen 5, but it showed no sign of ending in that ganglion, and probably continues to Abdomen 6. It will be observed that the decussation of A (*a*), Antenna II, takes place through the transverse bridge, *behind* the œsophagus. Similar elements have stained in Thorax III and Thorax V.*

The element A(*a*)Br (fig. 1) may be best considered here. It consists of a large cell on the ventral surface of the brain, from which a moderately thick fibre runs at first forwards and upwards to the dorsal surface. After turning outwards, the fibre runs backwards to a point immediately in front of the œsophagus, where it passes across

* In the present communication the thoracic ganglia are numbered consecutively I—XI. Of these I—VI form the anterior thoracic ganglion of the adult, whilst VII—XI *form the five posterior ganglia.*

to the other side, and then runs down the cord. On entering the thoracic ganglia, the fibre becomes very broad, and maintains a diameter many times that of any other fibre in the ganglionic cord. A single pair of elements of this kind exists, and it is easy to trace the fibres from the brain through the whole length of the ganglionic cord to the 6th abdominal ganglion. In the latter ganglion the fibre divides into several branches, but I have never obtained complete staining of these. The giant-fibres of the adult, with which these agree, are stated by Retzius* to divide in the last abdominal ganglion, and send branches through several of the nerve roots, which leave that ganglion.

In the brain this fibre gives off a few branches to the neuropile (fig. 1), but on its course down the cord, no collateral branches have ever stained, and I believe that none exist. The giant fibres differ in this respect from the other fibres of the class (A) which is now being considered.

Of the elements whose fibres do not decussate, A(*b*)Br. (fig. 1), may be taken as a type. The element starts with a cell of moderate size on the ventral surface of the brain, immediately anterior to the large cell of the giant fibre (A(*a*)Br). The fibre passes first forwards and upwards, giving off numerous branches to the anterior lobes of the brain on both sides, and then backwards through the brain, and down the ganglionic cord of the same side to the last abdominal ganglion. It gives off collateral branches to the neuropile of the ganglia through which it passes.

Similar elements have stained in Thorax III and Thorax IV.

B. Each element consists of a fibre starting from a cell in one of the thoracic ganglia, and running forwards to the brain. B Thorax V and B Thorax VI (fig. 1) are types of elements of this kind.

The cell of B Thorax V, lies in the lateral mass of ganglion cells. Soon after entering the neuropile the fibre gives off two branches, one running forwards and breaking up in the hinder portion of the ganglion immediately anterior, whilst the other runs backwards and breaks up in that immediately posterior. The main fibre turns inwards, crosses its fellow of the opposite side, and then bends forwards, running close to the median ganglionic cells, until it enters the brain. In the brain the fibre continues to run forwards, giving off many branches, and ends at about the level of the nauplius eye. The fibre has not been observed to give off collateral branches during its course through the thorax. Precisely similar elements occur in Thorax VIII, and somewhat similar ones in Thorax II.

In B., Thorax VI (fig. 1), the cell lies in the median mass of ganglion cells, and the fibre, on its course towards the brain, runs

* *Retzius,* " *Zur Kentniss des Nervensystems der Crustaceen,*" ' Biol. Untersuch.' *Neue Folge I, 1890.*

along the outer border of the neuropile.   It ends in the brain, at a point nearly as far forwards as the termination of B Thorax V, but somewhat lateral to it.   In this fibre also no collaterals have been observed in ganglia other than that in which the element originates. A similar element occurs in Thorax I.

C. Elements of this kind are inserted in ganglia Thorax VII—X in fig. 1.   Each consists of a small cell in the anterior portion of the lateral mass of ganglion cells.   The fibre, after taking a Z-shaped course through the neuropile, to which it gives off numerous arborescent branches, turns backwards, and after running between a fibre of Series D and the central mass of ganglion cells, ends in a tuft of fine branches at the posterior end of the ganglion next behind that in which the cell is situated.

D. These elements appear to be intimately associated with those of Group C, and both groups generally stain in the same preparations.

The cells of elements D lie in the posterior portion of the lateral ganglionic mass.   The fibre of each element passes forwards and inwards through the neuropile, giving off numerous arborescent branches to the latter.   On entering the next ganglion in front, the fibre has reached the outer border of the median ganglionic mass, and after giving off a little tuft of branches in front of the tuft in which one of the C elements ends, it pursues a direct anterior course, ending in a tuft of branches in the ganglion next but one to that in which it started.   This terminal tuft lies opposite the terminal tuft of one of the C elements, and behind the lateral tuft of the D element of the next ganglion.   The three tufts lie at exactly the same level in the cord, being all in the focus of the microscope at the same time.

II. Elements consisting of a cell in the ganglionic cord, giving off a fibre, which, after sending arborescent branches to the neuropile, passes out from the cord by one of the nerve roots.   Many of these elements, not improbably all, are motor, and in some cases the fibre has been traced through its whole course from the cell, until it breaks up on the muscle.   (Fig 1, E.   Thorax XI.)

Typical elements of this class are inserted in fig. 1 (Thorax VII— XI, E—J).   Each of these ganglia contains one or more elements of the various kinds.   E and F have the cell situated in the lateral mass of ganglion cells, and the fibre passes out through the anterior root of the ganglion and goes to one of the limbs.   In G and H the cell lies in the central mass, but the fibre passes through the same anterior root as E and F to a limb.   The element J, on the other hand, passes through the posterior root and goes to the muscles of the body wall.   It arises in a very small cell in the median mass, and the fibre runs for some distance outwards.   It then turns and takes a circular course through the neuropile, forming a complete loop, after which it passes outwards and enters the *posterior* nerve root.   From the anterior part of the

inner side of the loop a straight arm passes inwards and meets a similar arm from the opposite side. A direct fusion of the two arms has, however, never been observed.

III. Sensory elements, in which the cell lies outside the ganglionic cord.

These have been demonstrated by me up to the present only in the abdomen of lobster embryos. The cells are similar to those described by Lenhossék[*] and Retzius[†] in the earthworm, and by Retzius[‡], in polychaetes and molluscs. They are spindle-shaped and lie in the ectoderm (or immediately beneath it) of the dorsal surface of the abdomen. The distal end of the spindle either runs out as a fine fibre which ends freely, or the end of the fibre broadens out, forming a T-shaped figure on the end of the spindle. The fibre arising from the proximal end of the cell passes forwards and downwards to the nerve cord, where, after entering one of the ganglia, it bifurcates, giving rise to a Y-shaped figure. One of the branches runs forwards, the other backwards along the ganglionic cord. They have been seen to pass through two ganglia, but as to where they end I am not at present in a position to make a definite statement.

Theoretical.

I shall now endeavour to draw attention to some points of interest connected with the observations described above. With regard to the elements C and D, it might be maintained that they represent a purely embryonic arrangement, which has not yet reached the active state. This, however, appears to me improbable from the fact that the two systems remain in practically the same state from very early embryos, in which the eye-pigment has just begun to deposit, to the oldest larvæ (about one week) which I have been able to examine; and also from the fact that they take up methylene blue in a way which, according to present experience, only active nerve tissue does. Assuming then that the system is in the active state, it is important to notice the position of the three tufts of fibres, which stand opposite to each other, where elements C and D end. Although my observations agree entirely with those of Retzius, Kölliker, and the majority of recent investigators, in the fact that direct anastomosis of the portion of the element which stains with methylene blue has never been observed, it seems impossible to understand the meaning of this arrangement on any other supposi-

---

[*] Lenhossék, " Ursprung, Verlauf, und Endigung der sensibeln Nervenfasern bei Lumbricus," ' Arch. Mikr. Anat.,' vol. 89, 1892.

[†] Retzius, " Das Nervensystem der Lumbricinen," ' Biol. Untersuch.' Neue *Folge III, 1892.*

[‡] *Ditto, Neue* **Folge IV, 1892.**

tion than that here the nervous stimulus passes from one element to the other. It appears to me to be at least worth while to throw out the suggestion that the nervous energy resembles a static electrical charge, in the fact that the discharge takes place most readily through points. Wherever nerve endings have been demonstrated, the breaking up into finer and finer branches, which end freely, has been shown to take place.

On the view suggested, each nerve element resembles an electrical condenser capable of charging itself, and being suddenly discharged by an appropriate stimulus. It is interesting to note what would happen upon some such theory as this, supposing one of the elements D to be stimulated in any way. Imagine, for instance, the element D Thorax IX to be caused to discharge, either by an impulse from a sensory nerve, or from the brain. The main discharge would, we must suppose, pass into one of the motor elements such as E, by means of the fine branches which both send to the neuropile, and the muscle innervated by that particular fibre would be stimulated. A portion of the charge would, however, pass to the lateral and terminal tufts of D Thorax IX, and we may suppose that in this way D Thorax VIII and D Thorax X are made to discharge, as well as C Thorax VI. If we suppose the C elements to influence some other motor element in the neuropile, say F, then it will be seen by following out the result in the figure, that all the E and F elements upon one side of the thorax would be stimulated by the single stimulus to D Thorax IX.

With regard to elements of the class A, which start from a cell in one of the anterior ganglia and send a fibre down the cord, the fact that they give off collateral branches to the neuropile of each ganglion would seem to indicate that they in some way control an element, which also sends branches into that particular ganglion, and the suggestion would be that by their means a series of elements are stimulated all along the body by an impulse from the brain. On the other hand, by means of elements B, a particular ganglion would be placed in direct communication with the brain. This communication would be independent or correlated with a stimulus to (or from) all the ganglia through which the fibre passes, according to whether the absence of collaterals is the true condition of the element, or is due merely to imperfect staining.

A similar consideration will apply to the giant fibres (A(a)Br). It has been already stated that no collaterals have ever been observed on these fibres. According to Retzius branches go directly from their ends to the nerves of the last abdominal ganglion, and it, therefore, seems probable that they serve the purpose of putting some organ into direct communication with the brain. The most obvious suggestion would be that it is by their means that the muscles of the tail-fin, the steering apparatus of the animal, are controlled by the brain. There

is, of course, the possibility that the other fibres, which have been followed all along the cord to the last abdominal ganglion, also send branches through the nerve roots of this ganglion and serve a similar purpose. The presence of collateral branches upon them seems to me to be opposed to this view. The problems, however, suggested by the foregoing remarks can only be finally solved by means of physiological research.

My observations were made in the laboratory of the Marine Biological Association at Plymouth, with the assistance of a grant made by the Government Grant Committee. I hope shortly to publish a more detailed account with fuller illustrations.

V. "The Refractive Character of the Eyes of Horses." By Veterinary-Captain F. SMITH, F.R.C.V.S., F.I.C., Army Veterinary Department. Communicated by Professor MCKENDRICK, F.R.S. Received March 7, 1894.

The eyes of the horse are of great physiological interest, for there are certain features in connection with them not found in other animals.

While equine vision is principally monocular, it is quite undoubted that the horse can see objects situated to the right and left of his body at one and the same time; it is also equally certain that by directing both eyes forward, and producing a powerful internal squint, vision may be rendered binocular for objects situated directly to the front.

The corresponding points in the retina of the human eye, do not hold good in the case of animals which have their eyes situated laterally in the head and at some distance apart.

The pupil of the horse is a horizontal slit, which in full sunlight becomes so contracted that, with the presence of the corpora nigra, it is difficult to understand how sufficient light finds its way to the retina. A monocular retinal image in full sunlight must be a broken or imperfect one, for, filling up the centre of the horizontal pupil, are some large, black, soot-like bodies, the corpora nigra just referred to. These are attached principally to the superior pupillary margin of the iris, and completely block out the centre of the pupil when the latter is closely contracted. The horse is, I believe, the only animal possessing corpora nigra, and the function of these bodies is quite obscure.

It is essential that the horizontal pupil should always be kept horizontally placed, no matter what position the head may occupy : *every* upward and downward movement of the head necessitates a *rotation of the eyeballs* to ensure the pupils remaining horizontal,

and this rotation is produced by the oblique muscles of the eye.· As the horse can move its head vertically through an angle of about 90°, (the pupil all this time remaining horizontal) it can be seen how important is the function of these oblique muscles.

Though in direct sunlight the pupil closely contracts, yet in ordinary artificial light it dilates. This phenomenon can be turned to practical advantage in an ophthalmoscopic examination. Further, I have found that if daylight be thrown into the eye by means of a mirror the iris does not, as a rule, contract; this may be proved by placing a horse in a stable and excluding daylight from all but one source, and utilising that source to illuminate the eye by means of a mirror; a complete examination of the fundus can now be made, owing to the dilatation or, at any rate, non-contraction of the pupil.

For the last two years I have used no artificial light in my ophthalmoscopic work, and in the enquiry I am about to detail the whole was carried out in broad daylight. I have met with cases where the pupil has contracted on throwing a beam of daylight into the eye; such do not amount to more than 6 per cent. or 8 per cent. of the eyes examined.

Horses no doubt possess the power of accommodation, but I have never been able to satisfy myself that the instillation of atropine paralyses this power as it does in man; in fact, I think I can go so far as to say that in many cases no action is produced by this drug on the ciliary muscle, though the pupil be widely dilated. In a small proportion of cases I believe I have been able to observe some defect in accommodation under atropine.

My attention to this point was especially directed by a remark made by Messrs. Lang and Barrett* to the effect that a cat, the pupils of which they had thoroughly dilated with atropine, had no difficulty in pursuing and catching a mouse. Though it is difficult to apply such a satisfactory test to the horse, yet I have adopted measures which should, undoubtedly, have demonstrated any paralysis of accommodation had such existed.

The physiological pecularities of the horse's eye, which I have ventured briefly to draw attention to, induced me to examine the nature of the refraction, especially as a knowledge of it was calculated to be of practical importance and utility.

Disorders of vision are very common amongst horses; the most careful examination of such eyes often fails to reveal any pathological condition, but I think it will be possible to show that the nature of their refraction is calculated to throw light on an obscure condition.

We must accept it as practically correct that disorders of vision in

---

* " The Refractive Character of the Eyes of Mammalia," by W. Lang, F.R.C.S., and J. W. Barrett, M.B., ' Royal London Ophthalmic Hospital Reports,' vol. ll., Part II.

horses commonly exhibit themselves by "shying," a vice which may be attended by considerable danger. I shall hope to show that there is now a reasonable prospect of determining the cause of "shying" in the absence of pathological changes in the eye; further, that in that important branch of the veterinary art—the examination of horses for soundness—it should be possible to detect the kind of eye against which an intending purchaser should obtain a special warranty; and, lastly, as it is possible not only to determine the nature of the refraction, but also the amount of error which exists, we shall be able—when the needful public prejudice is overcome—to prescribe glasses for horses with every reasonable prospect of improving their vision.

This is not the first time the refraction of the horse's eye has been examined. Professor Berlin, of Stuttgart, published two papers cn the subject,* of these I have only been able to consult the second one. About the same time J. Hirschberg published his observations on the refraction of horses' eyes.†

In this country Messrs. Lang and Barrett, to whose paper I have already alluded, published an account of the refraction of the eyes of animals, including the horse. It is from their paper that I obtained two of the above references.

These observers obtained results which I have not been able to verify, and I think the reason of this admits of easy explanation:— In the case of Berlin the refraction was obtained by a direct examination of the fundus of the eye with the ophthalmoscope, a procedure the result of which appears to depend very largely on the refraction of the examiner, and his capacity for relaxing his accommodation.

In Lang and Barrett's excellent work the refraction was measured by means of "retinoscopy." They devoted their attention to the eyes of mammalia generally, but the number of horses tested by them was too small to admit of any general deductions being drawn.

According to Berlin, the majority of horses are slightly hypermetropic; he only met with eight cases of myopia in as many years. The amount of hypermetropia, according to this observer, is small, as a rule, lying between 1 D and 2 D. The largest amount found by him was 2·25 D.

---

* "Refraction und Refractions-Anomalien von Thieraugen," 'Tagblatt der 52 Versammlung Deutscher Naturforscher und Aertze in Baden-Baden,' p. 317. (Extract in 'Nagel's Jahres-Bericht.')

"Ueber den Physikalisch-optischen Bau des Pferdeauges," 'Zeitschrift für vergleichende Augenheilkunde,' 1882, Heft I.

† "Zur vergleichenden Ophthalmoscopie," Vortrag gehalten in der Berliner Physiologischen Gesellschaft am 10 Feb., 1882; 'Archiv f. Anat. und Phys.,' 1882; 'Phys. Abth.,' Heft 1 and 2, p. 81.

Of myopia, Berlin found in one case as much as 3 D, and in another, 2·75 D.

Hirschberg, adopting the same method of enquiry as Berlin, viz., direct examination of the fundus with the ophthalmoscope, found a considerable amount of astigmatism in the eyes of horses.

Lang and Barrett, in the six eyes they examined, found one was emmetropic, three hypermetropic and astigmatic, and two had slight mixed astigmatism. The astigmatism only once equalled 1 D, and the horizontal was always the least curved meridian.

In the enquiry I am recording, the number of horses examined was 54; these 54 horses, from one cause or another, furnished me with 100 eyes.

Of the 54 animals, 31 were mares and 23 were geldings; their ages varied from 4 years to 16 years; the largest number of horses of one age (5 years) was 13, 7 horses were 6 years old; 7 horses 7 years, 6 horses 8 years; the remaining numbers for each age varied from 1 to 4.

Before recording the results of this enquiry, I think it necessary to describe the method by which retinoscopy is carried out on the horse.

It has been shown by Messrs. Morton and Barrett* that the results of retinoscopy are liable to considerable error unless practised at the right portion of the fundus.

The observations made by these and other observers† are of the greatest value, for they have drawn attention to the difference in the reflex obtained in the human subject at the yellow spot and at the optic disc, and have settled that retinoscopy is only reliable when practised at the visual axis of the eye.

In the horse I found very early in the enquiry, that confusing and conflicting results might be obtained with the same eye when retinoscopy was practised at different parts of the fundus, for the reflex given at the optical axis was not the same as that obtained when the fundus was looked at obliquely. We have no knowledge whether the optical axis and visual axis of the horse are identical—for the purpose of this enquiry it has been assumed that they are.

The horse has no yellow spot, so that a valuable guide is lost in determining the position on the fundus at which to judge the reflex; on the other hand, the error of taking the reflex at the disc is not likely to occur, owing to the difficulty of seeing the disc with the head in the ordinary position.

* "A Clinical Investigation of the Methods of Practising Retinoscopy," 'British Medical Journal,' 16th January, 1886. See also 'Refraction of the Eye,' A. S. Morton, M.B., F.R.C.S.

† 'The Shadow Test in the Diagnosis and Estimation of Ametropia.' W. B. Beaumont.

The area of the most acute vision in the horse is probably the "tapetum," and that portion of the tapetum which lies in the optical axis of the eye is the part where all the observations contained in this paper have been made.

The horse to be examined is brought into an ordinary stable, and any windows likely to be reflected in the cornea are covered up. The observer stands facing the source of daylight, the eye to be examined being in shadow; standing opposite to the centre of the pupil (and looking at it in such a direction that a line passing through the eye would come out well below the base of the opposite ear), the light is reflected on to the retina at a minimum distance of 4 feet. A brilliant yellow reflex is obtained from the tapetum, by means of which we can readily fix our position relative to the pupil.

No means of restraint are employed, and though for a minute or two the horse works the eye under examination to and fro, thereby alternately altering the reflex, yet it soon comes to a standstill as he gets used to the reflection from the mirror.

The observer, by practice, automatically regulates his position, so as always to be opposite the centre of the longitudinal pupil, and to ensure that during any change he may make in his position he does not come nearer to the eye than the prescribed distance, a 4-foot gauge is lying on the floor at his feet, in the direction of the horse's head.

The reflex is taken in the horizontal and vertical meridians of the eye; it is very seldom that any difficulty is experienced in determining the direction in which the shadow is travelling; the real difficulty is in determining between two opposite shadows given consecutively in the same eye and in the same meridian. I think this latter phenomenon is caused by the horse using its ciliary muscle; with patience the true reflex of the resting eye will be obtained.

Having determined the direction of the shadows in both meridians, a trial lens is now placed in a frame and held in front of the eye under examination. The glass is brought quite close to the cornea, the centre of the lens corresponding to the centre of the cornea; the observer, standing at a minimum distance of 4 feet, throws the light into the eye and determines the reflex through the lens.

As we approach the lens which corrects the ametropia, some difficulty may be experienced in determining the direction taken by the shadow; sometimes it neither passes "with" nor "against" the mirror, but dies away from the circumference, producing an appearance resembling a dissolving view. In human practice this characteristic reflex, I believe, is considered to be due to astigmatism.

No part of the above examination is made under atropine; as previously explained, the pupil as a rule dilates sufficiently for a complete examination of the fundus to be made, and, so far as

paralysis of accommodation is concerned, little, if any, is produced even by repeated instillations of this drug.

My results have been calculated according to the rule given by Morton: For hypermetropia deduct +1 D from the weakest convex lens which causes the shadow to move with the mirror; for myopia deduct +1 D from the strongest concave lens with which the shadow continues to move with the mirror.

The following table (p. 420) exhibits the results of the enquiry. The table shows that of the 100 eyes examined—

> 51 were myopic and astigmatic.
> 2   „   hypermetropic and astigmatic.
> 6   „   affected with mixed astigmatism.
> 39 „   „   „   myopia.
> 1 with hypermetropia.
> 1   „   emmetropia.

The varieties of astigmatism which existed were as follow :—

> Compound myopic astigmatism   43
> Simple   „   „   8
> Compound hypermetropic astigmatism   1
> Simple   „   „   1
> Mixed astigmatism   6

In the eyes affected with myopia and astigmatism, the horizontal meridian was nearly always the meridian of least curvature. Berlin and Lang and Barrett had also observed the same fact. In my table of the 51 eyes there were only nine exceptions to this rule.

The amount of error which existed in each refraction was as follows :—

Myopia, 39 Eyes.

> Amount of error, 0·25 D ....   6 eyes.
> „   .   „   0·50 „   20   „
> „   „   1·25 „   5   „
> „   „   1·50 „   4   „
> „   „   2·25 „   2   „
> „   „   2·50 „   1   „
> „   „   3·00 „   1   „

Only once in 39 eyes was the amount of 3 D reached, whilst the most common amount of error was 0·50 D.

No.	Sex.	Age.	Right eye.		Left eye.	
			Vertical meridian.	Horizontal meridian.	Vertical meridian.	Horizontal meridian.
1	M	5	−0·50 D	−0·50 D	−0·50 D	−0·50 D
2	G	6	−0·50	−0·50	−0·50	−0·50
3	G	8	−2·50	−2·25	−1·75	−1·50
4	M	8	−0·50	−0·50	−1·50	−1·50
5	G	4	−0·50	−0·25	−0·50	−0·25
6	G	11	−1·50	−1·25	−0·50	−0·50
7	M	7	−0·75	−0·25	−0·50	−0·50
8	M	11	−1·75	+0·50	−0·25	+0·25
9*	M	13	−2·00	−2·25	−2·25	−2·25
10	M	5	−0·25	−0·25	−0·25	−0·25
11	M	5	−0·50	0	−0·50	0
12	M	5	—	—	−0·25	+0·25
13*	M	5	−0·50	−0·25	−0·50	−0·50
14	M	4	−1·75	−0·50	−1·25	−1·25
15	M	6	−0·50	−0·50	−0·50	−0·50
16	G	10	—	—	−2·00	−0·25
17	G	5	−0·50	−1·25	−1·25	−0·50
18*	G	7	0	−0·50	−0·50	−0·25
19*	M	7	−1·25	−0·50	−0·50	−0·50
20	M	14	−0·25	−0·25	−0·25	0
21	M	6	−0·25	−0·25	−0·25	−0·25
22	G		−0·50	0	−0·50	−0·25
23	G	8	−3·25	−2·25	−3·00	−3·00
24	G	4	−1·75	−1·25	—	—
25*	M	10	−1·50	−1·50	−1·50	−1·50
26*	M	5	−0·50	−0·50	−0·50	−0·50
27*	M	13	−0·50	−0·50	—	—
28*	M	5	−1·25	−1·25	−1·25	−1·25
29	M	12	−1·25	−0·50	—	—
30	M	6	−0·50	−0·25	−0·50	−0·25
31	M	5	−0·25	+0·25	+0·25	+0·50
32*	M	5	−0·50	−0·25	—	—
33	G	15	−0·25	+0·25	−0·50	−0·50
34	G	6	−1·75	−2·25	−1·25	−1·50
35	M	7	−1·25	−1·25	−1·50	−1·50
36	M	5	−0·50	0	−1·25	−0·25
37	M	8	−1·50	0	−1·25	−0·50
38	G	7	−1·75	−0·50	—	—
39	G	12	−0·25	−0·50	−0·50	−0·50
40	M	5	−1·25	−0·50	−1·25	−0·50
41	M	7	+0·25	+0·25	+0·25	0
42*	G	12	−0·50	−0·25	−0·50	−0·50
43	M	11	−0·50	−1·50	−0·50	−1·25
44	G	8	−0·50	−0·50	−1·25	−0·50
45	G	6	−1·25	−1·25	−0·50	−0·50
46	G	13	−1·25	0	−0·50	−0·25
47	G	4	0	0	−0·25	−0·25
48*	M	13	−2·75	−1·75	−1·25	−1·00
49	G	5	−2·25	−0·50	−1·25	−0·75
50	G	6	—	—	−1·25	−0·75
51	M	8	−0·50	−0·75	−0·50	−0·25
52	M	15	−0·25	+0·25	−0·50	−0·25
53	G	7	−0·50	−0·25	−0·50	−0·50
54*	M	16	−2·50	−2·50	−2·25	−2·25

* Those animals marked with a star were known to shy.

Compound Myopic Astigmatism (43 *Eyes*).

Amount of error, 0·25 D ·........ 21 eyes.
„   „   0·50 „ .... 5 „
„   „   0·75 „ .... 11 „
„   „   1·00 „ .... 4 „
„   „   1·25 „ .... 2 „

The most common amount of error was 0·25 D and 0·75 D.

Simple Myopic Astigmatism (8 *Eyes*).

Amount of error, 0·25 D .... 1 eye,
„   „   0·50 „ .... 5 „
„   „   1·25 „ .... 1 „
„   „   1·50 „ .... 1 „

Hypermetropia (1 *Eye*).

Amount of error, 0·25 D .... 1 eye.

Compound Hypermetropic Astigmatism (1 *Eye*).

Amount of error, 0·25 D .... 1 eye.

Simple Hypermetropic Astigmatism (1 *Eye*).

Amount of error, 0·25 D .... 1 eye.

Mixed Astigmatism (6 *Eyes*).

Amount of error, 0·50 D .... 5 eyes.
„   „   2·25 „ .... 1 eye.

The amount of error shown in these different refractions is small, so much so that many eyes might be regarded as emmetropic. In only about 33 per cent. of the myopic eyes did the amount of error exceed 1 D.

The number of astigmatic horses is remarkable, viz., 74 per cent., but we cannot agree with Hirschberg that the amount found is "intense." Of 59 astigmatic eyes only in nine did the error exceed 1 D.

The following horses in my table gave a history of "shying," viz., Nos. 9, 13, 18, 19, 25, 26, 27, 28, 32, 42, 48, and 54; from this list I have excluded three doubtful cases, but it must not be supposed that all the above horses "shied" so badly as to constitute a vice; nor

must I be understood to say that all shying is due to defective eyesight; further, it is possible for defective vision to be present without shying occurring, notably in Case 23 and several others.

Berlin considered the majority of horses to be hypermetropic; I have only met with one case of very low hypermetropia out of 100 eyes.

Conclusion.

1. The chief visual defect in horses is myopia with or without astigmatism.

2. The amount of error is not great.

VI. "Correction of an Error of Observation in Part XIX of the Author's Memoirs on the Organisation of the Fossil Plants of the Coal Measures." By W. C. WILLIAMSON, LL.D., F.R.S. Received March 28, 1894.

During the past two or three years we have acquired a much more accurate knowledge than we previously possessed of the structure of the leaves of the Lepidodendroid plants of the Coal Measures; and my last memoir, published in vol. 184 (1893) of the Philosophical Transactions, contains some new and not unimportant details on this subject. These facts were obtained from some finely preserved specimens of *Lepidodendron Harcourti* and of a Lepidophloios recently added to my cabinet.

But the value of these observations was seriously vitiated by an apparently small but very fundamental error into which I had fallen, an error which cannot be left uncorrected without misleading some of the palæontologists who honour me by consulting my writings on these subjects.

The students of fossil botany have long distinguished the leaves of the Lepidodendron from those of the Genus Lepidophloios by the shape of the leaf-scar left on the pulvinus or leaf-cushion on the fall of the deciduous leaf. These scars are always more or less quadrilateral in form, two of their angles following in opposite directions the long axis of the parent stem or branch, the other two pointing transversely across that axis. In Lepidodendroid leaves there is little difference in the lengths of these pairs of decussating angles, but in Lepidophloios the two transverse ones are much more prolonged than the vertical ones are, making the transverse diameter of the leaf-scar greatly exceed that in the opposite direction.

Whilst attached to the stem or branch of a Lepidodendron these leaves always point upwards towards its apex; and when I wrote the memoir referred to above, I had no reason for supposing that this *was not also* the case with the foliage of Lepidophloios, and my two

figures 33 and 34 were drawn in accordance with this belief; but during a visit recently paid to England by my old friend Professor Graf Solms-Laubach, he informed me that such is not the case. As soon as the leaves of Lomatophloios are developed, instead of ascending, they bend downwards, overlapping and hiding the leaf-cushion from view. I found from Count Solms that Lomatophloios is much more common in Germany than in England; consequently our friends across the water are more familiar with its aspect than we Englishmen are. Nevertheless, when thus enlightened by my friend, I found fragments in my collection which made clear to me that I had fallen into an error.

It follows from this fact that several of my figures in Part XIX illustrating the structure of these leaves are simply turned upside down, and require to be reversed. This is the case with fig. 13 on Plate 2, and with figs. 33, 34, 36, and 37 on Plate 4. Thus drawn, these figures misrepresent the relative positions of three important internal structures, viz., the Leaf-trace, the bifurcating Parichnos, and what has received the name of the Ligule. Our attention was, I believe, first called to this latter organ by the late Professor Sturr, of Vienna, but it has subsequently been further commented on by Professor Bertrand, of Lille, in conjunction with M. Hovelacque, of Paris. It is now clear that the Leaf-trace is the more central organ, having the so-called Ligule above and the double Parichnos below it. Apart from their inversion, my figures of these organs are absolutely accurate. Fig. 13, in Plate 2, though belonging to a true Lepidodendron, represents the Parichnos g, as resting upon the Leaf-trace c'. In thus arranging these two organs in a Lepidodendron, I was misled by the specimen represented in Plate 4, fig. 36. All these errors, arising from a common misunderstanding, are now corrected. Of course it follows that all such terms as *upper* and *lower*, used in the text describing the above-named five figures, must be severally reversed.

On p. 9 of my memoir I criticised the application by MM. Bertrand and Hovelacque of the name Ligule to the organ to which they had assigned it, because they thus identified the organ as being the homologue of the appendage so named in the living Selaginellæ. In the latter case the Ligule springs from the upper surface of the leaf, whereas the mistaken impression under which I laboured, led me to believe that in the fossil forms it sprang from the under side. Of course, any argument based upon the latter supposed fact now falls to the ground. At the same time, like Solms-Laubach, I should be cautious in accepting this supposed homology as proven. Nevertheless, some curious points of resemblance between the primæval and the recent types make this identity far from impossible.[*]

[*] *It appears to me that much uncertainty exists amongst Palæobotanists re-*

VII. " Report on some of the Changes produced on Liver Cells
by the Action of some Organic and Inorganic Compounds."
By T. LAUDER BRUNTON, M.D., F.R.S., and S. DELÉPINE,
M.B.   Received March 14, 1894.

We have, on a former occasion, given an account of the *scope of the
investigation, and of the methods used, of some preliminary observations*[*]
which we have found it necessary to make.

Briefly speaking, our object was to ascertain the action of drugs on
the cells of the liver and to connect, if possible, the changes in the
cells with the physiological action of the drugs and their chemical
structure.

Certain drugs were selected by one of us (Brunton) as being
most suitable for this investigation.   These drugs were the follow-
ing :—

Benzene	$C_6H_5 \cdot H$
Phenol	$C_6H_5 \cdot OH$
Toluene	$C_6H_5 \cdot CH_3$
Aniline	$C_6H_5 \cdot NH_2$
Toluylene diamine (meta) C_6H_3	$\begin{cases} CH_3 \ (1) \\ NH_2 \ (3) \\ NH_2 \ (4) \end{cases}$
Chrysophanic acid	$C_{10}H_4O_4$
Pilocarpine nitrate	$C_{11}H_{16}N_2O_3 \cdot HNO_3$
Atropine	$(C_{17}H_{23}NO_3)_2H_2SO_4$
Ammonia	NH_3
Ammonium chloride	$NH_4 \cdot Cl$
Nitric acid	HNO_3
Sodium iodide	NaI

We have recorded the *various appearances which we have observed as
the result of the purely physiological stimulation of the liver produced by
the ingestion and digestion of a meal*, and have noticed that *the most
important changes indicating various states of activity were* :—

1. The size of the cells.
2. The distinctness of the mitoma and of the cellular cleavage.

specting the structures that distinguish *Lepidodendron* from *Lepidophloios.* Some
trust to the several forms of the sections of the leaves, leaf-scars and leaf-
cushions; others to the upward or downward directions taken by the elongated
portions of the leaves.   In fact the question demands a more critical and conclu-
sive investigation than it has yet received.—*Note*, April 19, 1894.

* ' *Roy. Soc. Proc.*,' Oct. 22, 1891, vol. 50, p. 209, and Paper placed in the
Archives.

3. The size and arrangement of the meshes of the mitoma of the cells.

4. The size of the biliary canaliculi.

5. The amount and distribution of the glycogen in the cells and in the lobules of the organ.

6. The amount and distribution of granules giving the reaction characteristic of inorganic ferric salts.[*]

We also recorded changes affecting other parts, but we need not consider them for the present.

We will now give an *account of the appearances produced in the liver soon after the administration of the compounds mentioned above, either subcutaneously, by the rectum, or by the mouth* (the latter in only two cases) :—

1. To rabbits that had taken a moderate amount of food (50 grams of carrots from 7 to 9 hrs. before death—in two cases only the time was less than 7 hrs.) ;

2. To rabbits that had not been fed for at least 24 hrs. before death.

To estimate the changes produced, the organs of animals to which drugs had been administered were compared in each case with those of animals in the same stage of digestion, but to which no drug had been administered. Thus, when we say that a drug causes an enlargement of the meshes of the mitoma, or renders them more distinct or indistinct, or causes an accumulation of iron, we always mean that *the state in which the cells would have been at the same stage of digestion has been modified in the direction indicated.*

As the measurements of cells and parts of cells necessitate the careful drawing of a large number of cells with the camera lucida, the report, in its final shape, cannot yet be given, but, as all the appearances observed have been taken note of during the progress of the investigation, we are in position to give an idea of the results which have so far been obtained, but which we are not yet able to express in numbers, and compare as accurately as we hope to do when all our measurements are completed.

Action of Pilocarpine on a Fasting Liver.

A.—*Last food* given 25 hrs. before death.

Pilocarpine nitrate (grain $\frac{2}{3}$ = gram 0·042, dissolved in 10 c.c. of water) was injected into the rectum 1 hr. and 28 mins. before death.

---

[*] *Loc. cit.*, and also "Contribution to the Study of the Vertebrate Liver," 'Roy. Soc. Proc.,' Nov. 20, 1890, vol. 49, p. 64; "On the Normal Storage of Iron in the Liver," 'Practitioner,' vol. 45, p. 94.

B.—There were very few psorosperms in the liver, which was of small size.

Cells small, or of medium size.

Outlines of the cells and the mitoma much clearer than normal.

Meshes of the mitoma pretty large; some grouped round the lateral bile canaliculi.

Main and lateral bile canaliculi very distinct and very large.

Glycogen reaction normal, *i.e.*, doubtful and diffuse. Only slight traces of *sugar* could be obtained in 24 hrs. after death.

Iron reaction less marked than normal.

C.—The state of the mitoma of the cells, and the amount of iron indicate secretory activity.

This may be taken as a type of liver in a state of secretory activity.

Action of Pilocarpine on a Fasting Liver.

A.—*Last food* given about 26 hrs. before death, the food not eaten being removed 17 hrs. before death. (This is an exception to the rule generally followed.)

Subcutaneous injection of ½ grain of pilocarpine (a little more than gram 0·03) was given 1 hr. 30 mins. before death.

B.—*Liver* apparently healthy.

Cells large and swollen looking.

Outline of the cells and the cellular mitoma extremely distinct.

Meshes of the mitoma very large.

Bile canaliculi large and distinct.

C.—These changes correspond to those observed in an active liver, and may be taken to indicate secretory activity.

Action of Pilocarpine on a Fed Liver.

A.—*Last food* given 7 hrs. before death.

Death blow 2 hrs. 43 mins. after a first subcutaneous injection of ⅔ grain (gram 0·042) of pilocarpine (a second injection of the same quantity having been given 38 mins. before death).

B.—*Liver* moderately diseased, containing a few large psorospermic masses, and being somewhat above the average size.

Cells generally large but variable in size.

Outlines of cells and the *mitoma* even more distinct than normal.

Meshes of the mitoma large, specially round the nuclei.

Bile canaliculi indistinct.

Glycogen reaction about normal, slightly diminished.

Sugar reaction, 24 hrs. *post mort.*, slightly diminished.

Iron reaction much diminished, both in the diffuse and in the granular form.

C.—The changes produced in the fed liver correspond closely with those observed in the fasting organ, and may be taken as typical of secretory activity.

Action of Toluene on a Fasting Liver.

A.—*Last meal* 31 hrs. before death.

Rectal injection of 1 gram (15·5 grains) of toluene suspended in 10 c.c. of thin mucilage, 56 mins. before death.

B.—*Liver* of moderate size, with pretty abundant psorospermic lesions.

Cells small and medium sized.

Outline and mitoma clear, much clearer than normal.

A few large *meshes*, specially grouped round the nucleus.

Bile canaliculi not generally distinct, when distinct very narrow.

Glycogen reaction distinct round the hepatic vein, and therefore increased.

Sugar formed in 24 hrs. *post mort.*, much more abundant than normal.

Iron reaction almost absent, and therefore less than normal.

C.—The action resembles somewhat that of pilocarpine, but differs from it on account of the increase of glycogen.

Action of Toluene on the Fasting Liver.

A.—*Last meal* 20 hrs. before death.

Subcutaneous injection of about 0·06 gram (*i.e.*, = about 0·9 grain) of pure toluene 4 hrs. 45 mins. before death.

B.—*Liver* apparently not diseased.

Cells pretty large.

Outline of cells and mitoma more distinct than normal.

Meshes of mitoma a little larger than normal.

Bile canaliculi very distinct.

Blood capillaries rather congested.

C.—There is stimulation of the cells resembling, to a certain extent, that produced by pilocarpine, but much less marked.

Action of Toluene on a Fed Liver.

A.—*Last food* 8 hrs. before death.

Subcutaneous injection of about 0·06 gram of pure toluene 4 hrs. 53 mins. before death.

B.—*Liver* apparently not diseased.

Cells rather small.

Outline of cells and mitoma distinct.

Meshes large.

Bile canaliculi distinct here and there.

Blood capillaries excessively congested.

C.—With the exception of the size of the blood capillaries, there is no very marked departure from the normal.

Action of Benzol on a Starving Liver.

A.—*Last meal* 31 hrs. before death (a few very small bits of carrots were unfortunately left within reach of the animal during injection).

Rectal injection of 1·15 gram (*i.e.* 17·8 grains) of benzol, suspended in 10 c.c. of thin mucilage 2 hrs. 30 mins. before death.

Subcutaneous injection of about 0·5 c.c. of pure benzol 2 hrs. 5 mins. before death.

B.—*Liver* large, with abundant psorospermic lesions.

Cells pretty large.

Mitoma and outline distinct, much more so than normal.

Meshes of mitoma large.

Bile canaliculi very distinct, main canaliculi in portal zone.

Glycogen reaction very slightly increased, diffuse.

Sugar formed in 24 hrs. *post mort.*, very little, about normal.

Iron reaction very slight, normal ?

C.—The action is very similar to that of pilocarpine in every respect.

Note.—In this case it is possible that the munching of a few bits of carrot may have stimulated the liver; but the quantity so ingested was very small, and probably had no distinct effect.

Action of Benzol on a Fed Liver.

A.—*Last meal* 8 hrs. 34 mins. before death.

Rectal injection of 1 gram of benzol, suspended in 10 c.c. of thin mucilage, 1 hr. before death.

B.—*Liver* very large, the largest observed. Psorospermic lesions in moderate amount.

Cells very large, swollen-looking.

Mitoma and outline of cells very clear.

Meshes of mitoma large, specially round the nucleus.

Bile canaliculi indistinct.

Glycogen reaction very abundant round hepatic vein, somewhat diffuse elsewhere.

Sugar produced *post mort.* in 24 hrs. less than normal.

Iron reaction much diminished.

C.—This action resembles closely that of pilocarpine.

Action of Sodium Iodide on a Fasting Liver.

A.—*Last meal* 25 hrs. before death.

Rectal injection of 1·75 grams (*i.e.*, about 27 grains) of· iodide of sodium dissolved in 10 c.c. of water 1 hr. before death.

B.—*Liver* medium sized, with very few psorospermic lesions.

Cells medium sized.

Mitoma and outline of cells pretty distinct.

Meshes of mitoma generally medium sized, some very large round the nuclei.

Bile canaliculi distinct at places but very small.

Glycogen, slight amount round the hepatic vein.

Sugar formed in 24 hrs. *post mort.*, the largest quantity produced except after toluylene diamine.

Iron reaction very indistinct, less than normal.

C.—Resembles pilocarpine except as regards the tendency of accumulation of glycogen.

Action of Sodium Iodide on a Fed Liver.

A.—*Last meal* 7 hrs. 40 mins. before death.

Rectal injection of 2 grams (31 grains) of sodium iodide dissolved in 10 c.c. of water 42 mins. before death.

B.—*Liver* larger than normal, psorospermic lesions very few.

Cells irregular, some very large, some small, angular.

Mitoma and outline of cells very distinct, more so than normal.

Meshes of the mitoma large, some very large round nuclei.

Bile canaliculi indistinct.

Glycogen, largest amount seen in any liver.

Sugar formed in 24 hrs. *post mort.*, large amount, perhaps a little more than normal.

Iron reaction very slight, less than normal.

C.—Action resembles that of pilocarpine, but in addition there is a marked tendency to accumulation of glycogen.

Action of Chrysophanic Acid on a Fasting Liver.

A.—*Last meal* 28 hrs. before death (animal allowed to eat a small bit of carrot during the injection).

Rectal injection of 0·1 gram (*i.e.*, about 1½ grains) of chrysophanic acid suspended in 10 c.c. of thin mucilage 2 hrs. 23 mins. before death.   .

B.—*Liver* moderately large with very few psorospermic lesions.
Cells generally small or medium sized.
Outline of cells and *mitoma* clear, much more so than normal.
Meshes of mitoma generally small, a few large ones round the nucleus.
Bile canaliculi, main and lateral distinct.
Glycogen reaction increased, slight round the hepatic veins.
Sugar formed in 24 hrs. *post mort.*, more abundant than normal.
Iron reaction very slight, less than normal.

C.—This action resembles that of pilocarpine.

Action of Ammonium Chloride on a Fasting Liver.

A.—*Last meal* 28 hrs. before death.
Rectal injection of 1 gram (15·5 grains) of ammonium chloride dissolved in 10 c.c. of water 2 hrs. before death.

B.—*Liver* small, with very few psorospermic lesions.
Cells large.
Mitoma and outline of cells pretty distinct.
Meshes of mitoma large in some places.
Bile canaliculi generally indistinct.
Glycogen doubtful diffuse reaction (normal).
Sugar formed in 24 hrs. *post mort.*, very little (normal).
Iron reaction slight, about normal.

C.—Stimulation of the cells is indicated by the changes in the mitoma, similar to, but not so marked, as those produced by pilocarpine.

Action of Ammonium Chloride on a Fed Liver.

A.—*Last meal* 9 hrs. 20 mins. before death.

Rectal injection of 1 gram of chloride of ammonium in 10 c.c. of water (sp. gr. 1025) 1 hr. 5 mins. before death.

B.—*Liver* large, with few psorospermic lesions.
Cells large, looking swollen.
Mitoma and outline of cells very distinct (more than normal).
Meshes of mitoma large round the nucleus.
Bile canaliculi narrow, distinct only in portal zone.
Glycogen abundant, chiefly round the hepatic (more than normal).
Sugar formed in 24 hrs. *post mort.*, large amount (a little above normal).
Iron reaction entirely absent (much less than normal).

C.—This is a stimulating action similar to that of pilocarpine, but there seems to be in addition a tendency to the accumulation of glycogen.

Action of Toluylene Diamine (Meta) on a Fasting Liver.

A.—*Last meal* 29 hrs. before death. 4 hrs. 10 mins. before death, gram 0·5 (grains 7¾), suspended in 10 c.c. of mucilage, injected per rectum. 3 hrs. 36 mins. before death, gram 0·06 (*i.e.*, 1 grain), dissolved in 5 drops of benzol injected subcutaneously. 20 mins. before death, gram 0·06 given in a slice of carrot.

B.—*Liver* large, with pretty abundant psorospermic lesions.
Cells generally large, but variable in size.
Mitoma and outside of cells not very distinct, but clearer than normal.
Meshes of mitoma medium sized, larger than normal.
Bile canaliculi indistinct.
Glycogen reaction well marked round the hepatic vein, *i.e.*, more marked than normal.
Sugar formed in 24 hrs. *post mort.* more abundant than normal.
Iron reaction almost entirely absent.

C.—The action of toluylene diamine in this case resembles that of pilocarpine, except as regards the production of sugar *post mort.*

Action of Toluylene Diamine (Meta) on a Fasting Liver.

A.—Animal killed 24 hrs. after its *last meal.* A little under gram 0·5 (= 7 grains), finely divided, and suspended in 10 c.c. of water, injected per rectum 2 hrs. 13 mins. before death.

B.—*Liver* moderately large, a pretty large number of psorospermic lesions were present.
Cells generally large.

Mitoma and outline of cells more distinct than normal.
Meshes large.
Bile canaliculi where distinct small, but generally indistinct.
Glycogen reaction increased immediately round the hepatic vein.
Post-mortem production of sugar in 24 hours more marked than in any other case.
Iron reaction almost absent.

C.—With the exception of the *post mort.* production of sugar this action resembles closely that of pilocarpine.

Action of Toluylene Diamine (Meta) on a Liver immediately after the taking of Food.

A.—*Last ordinary meal* 25 hrs. before death; 17 *hrs.* 30 *mins. before death* the animal was given carrots with gram 0·09 of toluylene diamine; 1 hr. 30 mins. before death a new dose of 0·06 gram of toluylene diamine was given with 10 grams of carrots by the mouth.

B.—*Liver* pretty large, psorospermic lesions pretty abundant.
Cells large.
Mitoma and outline very distinct.
Meshes large, chiefly round the nucleus.
Bile canaliculi generally indistinct; where distinct, small.
Glycogen reaction slight round the hepatic vein (about normal).
Sugar formed in 24 hrs. *post mort.*, more abundant than normal.
Iron reaction entirely absent, normal.

C.—Action similar to that of pilocarpine, with the exception of the production of sugar *post mort.*

Action of Nitric Acid on a Starving Liver.

A.—*Last meal* 25 hrs. before death.
Rectal injection of 1 c.c. of nitric acid diluted in 10 c.c. of water (sp. gr. 1024), 1 hr. 15 mins. before death.

B.—*Liver* large, with few psorospermic lesions.
Cells small or medium-sized.
Mitoma and outline of cells not very distinct, but more so than normal.
Meshes of mitoma distinctly larger than normal.
Bile canaliculi, main very distinct, lateral often distinct.
Glycogen reaction doubtful, diffuse, normal.
Sugar formed *post mort.* in 24 hrs., very small amount, about normal.
Iron reaction very slight, less than normal.

C.—*The* action resembles much that of pilocarpine.

Action of Nitric Acid on a Fed Liver.

A.—*Last food* 7 hrs. 45 mins. before death.

Rectal injection of 0·5 c.c. of nitric acid diluted with 10 c.c. of water (sp. gr. 1011 to 1012) 50 mins. before death.

B.—*Liver* medium size, quite healthy.

Cells large, swollen looking.

Mitoma and outline of cells very clear, normal.

Meshes of mitoma large round the nucleus (normal).

Bile canaliculi indistinct.

Glycogen very slightly increased.

Sugar formed in 24 hrs. *post mort.*, normal amount.

Iron reaction much less than normal.

C.—This action resembles closely that of pilocarpine.

Action of Aniline on a Starved Liver.

A. This experiment is not quite comparable with the others. A rabbit, after being treated in the usual way, received *an injection* of 1 gram of *acetate of ammonium* per rectum, and 20 mins. afterwards another 1·5 gram. This apparently produced no effect, and the rabbit was not killed. It *was then fed* 42 hrs. before its death; ¾ hr. before it was killed, 1 gram of aniline thoroughly mixed with water was injected into the rectum. This produced well-marked symptoms, as in XXIII.

B.—There were few psorospermic lesions, the *liver* was very small.

Cells unequal; some small, some medium size.

Mitoma and outlines of cells indistinct generally, but distinct at places.

Meshes generally small.

Main bile canaliculi distinct in the portal zone.

Glycogen reaction indistinct, diffuse.

Sugar produced in 24 hrs. *post mort.*, very small.

Iron reaction considerably increased.

C.—The secretory activity of the liver did not seem to be much affected by aniline, but this substance seems to have had destructive action on some cells, and has caused a considerable splitting of organic compounds containing iron. In certain parts the cells were dropsical and possibly necrosed.

Action of Aniline on a Fasting Liver.

A.—*Last meal* 25 hrs. before death.

1 gram (15·5 grains) of pure aniline mixed with 10 c.c. of water *injected* into the rectum 1 hr. 32 mins. before death.

B.—*Liver* of small size with only a few psorospermic lesions.
Liver cells medium sized.
Outline of cells and mitoma indistinct (*i.e.*, normal in appearance).
Meshes of the mitoma small, normal in appearance.
Bile canaliculi, main and lateral, very distinct.
Glycogen reaction doubtful, diffuse, normal.
Sugar produced in 24 hrs. post mort. a little more than normal.
Iron reaction slight and round hepatic veins, *i.e.*, normal.

C.—Aniline in this case does not seem to have produced any marked effect on the liver.

Action of Phenol on a Fasting Liver.

A.—*Last food* given 25 hrs. before death.
Rectal injection of 0·83 gram (about 12 grains) of absolute phenol dissolved in 10 c.c. of water 46 mins. before death.

B.—Moderate amount of psorospermic lesions.
Liver moderately large.
Cells small, but not below normal.
Mitoma and outline of cells indistinct, but not more so than normal.
Meshes of mitoma generally small, irregular.
Glycogen reaction indistinct, about normal.
Sugar produced in 24 hrs. *post mort.* very slightly increased.
Iron reactions not very distinct, altered.

C.—Phenol does not seem in this case to produce marked alterations of secretory activity.
Note.—The cells are in many places much vacuolated, breaking down, and probably in a state of incipient necrosis.

Action of Phenol on a Fed Rabbit.

A.—*Time of last meal*, 7 hrs. 15 mins. before death.
0·5 gram (about 7¾ grains) of phenol dissolved in 10 c.c. of water *injected* into the rectum 50 mins. before death.

B.—Psorospermic lesions of the liver moderately abundant.
Organ large.
Cells large.
Outline of cells and mitoma clear, but less so than normal.
Size of the meshes of the mitoma a little less than normal.
Bile canaliculi generally indistinct.
Glycogen reaction much diminished and diffuse.

Sugar obtained in 24 hrs. *post mort.,* a little more than half the normal amount.

Iron reaction considerably increased.

C.—Phenol in this case evidently interfered with constructive metabolism, and caused an increased decomposition of organic compounds containing iron.

Note.—In this case there were also evidences of beginning necrosis of patches of liver cells.

Action of Atropine on a Fed Liver.

A.—*Last food* given 5 hrs. 45 mins. before death.

6 hrs. 30 mins. before death a *subcutaneous injection* of $\frac{1}{60}$ of a grain was given, $\frac{1}{4}$ hr. after another $\frac{1}{60}$ grain, and after another $\frac{1}{4}$ hour $\frac{1}{60}$ grain. Afterwards successive doses of $\frac{1}{10}$ grain of atropine were given with the food up to nearly $\frac{1}{2}$ grain (0·03 gram); the animal being thus saturated with atropine both before and during the last meal.

B.—*Liver* considerably altered by psorospermic lesions, but about normal in size.

Cells large.

Outlines of cells and the mitoma very indistinct.

Meshes of the mitoma generally small, but a few large ones were faintly indicated.

Bile canaliculi generally indistinct; where distinct they were very narrow.

Glycogen reaction well marked, but less so at the periphery of the lobule than it should have been.

Iron reaction did not show anything special.

C.—These changes are taken as the type of a liver in which the secretory activity is diminished.

I. *Action of Atropine on a Fed Liver.*

A.—*Last food* given 7 hrs. before death.

Subcutaneous injection of $\frac{1}{15}$ of a grain (gram 0·002) of sulphate of atropine was given 3 hrs. 30 mins. before death.

B.—There were only a few psorospermic lesions in the organ.

Cells large.

Outlines of the cells and the mitoma not very distinct.

Meshes of the mitoma small.

Bile canaliculi, where distinct, were narrow.

C.—These appearances were those of a fasting liver, with the ex-

ception of the size of the cells, and are taken to correspond to diminished secretory activity.

Action of Ammonia on a Fasting Liver.

A.—*Last food* given 25 hrs. before death.

1 c.c. of liquor ammoniæ, diluted with 9 c.c. of water, was *injected* into the rectum 12 mins. before death (death accidental, possibly accelerated by, but not, certainly, due to the drug).'

B.—*Liver* very slightly diseased (psorospermosis) and of small size. *Cells* small.

Mitoma more indistinct than normal, and the cellular cleavage also.

Meshes of the mitoma smaller than normal.

Bile canaliculi seldom distinct.

Glycogen reaction normal, *i.e.*, there were no distinct glycogenic granules.

Sugar reaction, obtained after maceration in water for 24 hrs., was a little more marked than under normal circumstances.

Iron reaction considerably increased, but diffuse.

C.—Ammonia seemed in this case to have an action somewhat similar to that of atropine, but to cause a greater splitting of organic combinations of iron.

Action of Ammonia on a Fed Liver.

Last food given 8 hrs. and 30 mins. before death.

1 c.c. of liquor ammoniæ, diluted with 10 c.c. of water, was administered per rectum 65 mins. before death.

B.—*Liver cells* rather large.

Outline of the cells and the cytomitoma indistinct, instead of being very distinct, as they should have been.

Meshes of the mitoma small instead of large.

Bile canaliculi generally indistinct.

Glycogen reaction well marked in the hepatic zone only, instead of being more general.

Sugar produced in 24 hrs. after death was normal.

Iron reaction more marked than normal, but was diffuse; the granules were, on the contrary, rather less than normal.

C.— Generally speaking, the results were the same as in the fasting state, and, with the exception of the changes in the iron reaction, were similar to those produced by atropine.

Provisional Conclusions.

The effect which the administration of various drugs has on the distinctness of the cellular mitoma and on the distribution or arrange-ment of that mitoma and of the paramitoma, resembles, in the case of a certain number of drugs, that of pilocarpine, and in others that of atropine. The first drugs may be said to stimulate glandular activity, the latter to restrain it; only a few of those experimented with seemed to have neither a stimulating nor a depressing action.

On this basis we may subdivide the compounds studied into three groups.

1. Stimulating or *excito-secretory group*, with pilocarpine for a type.
2. Neutral group.
3. Depressing or *depresso-secretory group*, with atropine for type.
1. *Excito-secretory group.*

Of the following compounds, those heading the following list pro-duced the most marked changes in the mitoma of the cells:—

Toluene, benzol, sodium iodide, pilocarpine, chrysophanic acid, ammonium chloride, toluylene diamine, nitric acid.

(Aniline seemed in one case to have a stimulating effect, but this was doubtful.)

2. *Neutral group.*

No drug was altogether neutral, but two drugs seemed to have little depressing, and still less exciting, action, though they evidently produced degenerative changes in the cells; in the doses used, they acted probably too powerfully as poisons. These compounds were aniline and phenol.

3. *Depresso-secretory group.*

The following compounds belong to this group:—

Phenol, atropine, ammonia.

In each of the two great groups it is possible to recognise marked differences based on the influence which the drugs had (1) on the storage of glycogen; (2) on the accumulation of compounds giving the reaction of inorganic ferric salts in the liver.

1. In the *excito-secretory* group.

* *Glycogenic Function.*

A.—The following drugs *caused marked increase of glycogen in the liver:—*

Sodium iodide, toluylene, diamine, chrysophanic acid (toluene ?) (ammonium chloride ?)

B.—The following gave rise to *no marked increase of glycogen*, and sometimes even to a diminution:—

(Ammonium chloride ?), nitric acid, pilocarpine, benzol.

** *Ferrogenic Function.*

A.—The following drugs caused *a very marked diminution in the amount of free iron in the liver :*—

Sodium iodide, toluene, toluylene diamine.

B.—The following caused' *a diminution in the quantity of iron, but not to the same extent* as the first, and the iron was often so distributed as to remind one of the appearances observed in an active liver:—

Chloride of ammonium, nitric acid, pilocarpine, benzol (in the fed liver).

C.—*In one case only a doubtful increase of iron was found :*—
Benzol (in the fasting liver).

2. In the group of *depresso-secretory compounds.*

A.—*Ammonia* caused a diminution of the glycogen and an increase of iron.

By its influences on the accumulation of glycogen and of iron, *phenol* acts distinctly in the same way as the depresso-secretory compounds; thus it caused diminution in the glycogen and an increase in the iron.

Aniline caused little change in the glycogen, but a great accumulation of iron in one case. The action of aniline evidently requires to be studied more specially.

B.—*Atropine* caused a slight diminution in the glycogen and little change in the iron.

General Concluding Remarks.

We are satisfied that much is to be learned of the *affinities of drugs* and of their *physiological action* by the methods which we have been using in this study. The anticipation of unknown difficulties in a field practically new has caused us to spend much time in observations which have not all proved of much use. We know now how to obtain those results which are most useful. We are repeating some of the experiments in order to test the value of our first results, and we are slowly repeating the measurements which have already taken such a considerable amount of time. It would be unwise in the present state of the inquiry to attempt to give more dogmatic conclusions than those we offer provisionally.

VIII. " Note on the Production of Sounds by the Air-bladder of certain Siluroid Fishes." By Professors T. W. BRIDGE and A. C. HADDON. Communicated by Professor A. NEWTON, F.R.S. Received April 17, 1894.

Dr. William Sörensen, of Copenhagen, has drawn our attention to the fact that, in our memoir on " The Air-bladder and Weberian Ossicles in the Siluroid Fishes," published in the ' Philosophical Transactions' last year (vol. 184, pp. 65—333), we failed to do justice to the results of certain investigations which are embodied in his paper, entitled " Om Lydorganer hos Fiske : en physiologisk og comparativ-anatomisk Undersögelse," and published at Copenhagen in 1884. In this paper Dr. Sörensen treats of the various methods of sound production in Fishes in general, and in the case of the Siluroid Fishes, describes the production of sounds by means of certain stridulating mechanisms (friction of the dorsal and pectoral spines), the " elastic spring " apparatus, and the paired extrinsic muscles of the air-bladder in the *Pimelodinœ*. We do not here wish to criticise his morphological conclusions, but to point out that, contrary to the assumption on pp. 270 and 301 of our paper, Dr. Sörensen did make some experiments on living Fish. After describing the nature of the " elastic spring " and the disposition of its muscles in the South American Siluroid, *Doras maculatus*, on p. 88 of his paper, he says, concerning this Fish :—

" *Observations on the Production of Sounds.*—When one opens the abdomen of a recently caught fish and quickly extracts the intestines with everything that is attached to them so that the swim-bladder is exposed, one can very easily perceive that the swim-bladder is in a convulsive vibratory motion at the same time that the sound is produced. It is a very deep murmuring note, which is so strong that it can be distinctly heard at a distance of 100 ft. when the animal is out of the water. Unlike the sounds produced by the movements of the pectoral fin, the tones produced by the swim-bladder are not grating, and therefore not disagreeable to the ear. As far as I am able to judge, the swim-bladder commands only one note, but this can be stronger or weaker according to the will of the fish. If one moves the fingers backwards and forwards over the swim-bladder, one will soon perceive that the vibrating motion, beginning at the same time as the sound, is strongest in the front, especially at the " muscle-springs," and also that the muscles passing to these contract at the same time that the sound is produced. If the muscles are cut through, the sound is no longer produced. If one makes a little hole in the swim-bladder, the sound will not be very much weaker; but if

a larger opening is made in it, the sound will considerably diminish in strength. If one takes out the swim-bladder, the note will become very weak, but may still be heard; it is then produced only by the vibrations of the springs. By ordinary observations I have not been able to prove that those bars or cross-walls (transverse septa) which project into the lumen of the chief compartment of the swim-bladder, or its external diverticula, assist in the production of sound; but if one compares this with what I state later on in Pseudaroides, I believe it would prove very doubtful, on account of their incomplete partition walls, that the diverticula of the swim-bladder even to a great degree serve to strengthen the sound by the air passing to and fro over them. By looking more particularly one will observe that the anterior cutaneous plate at the side of the body also vibrates when the sound is produced. I suppose that the action of the ligament, which connects it with the circular plate of the muscular spring, besides transferring the sound vibrations of the swim-bladder to the water, consists in preventing a too violent recoil of the spring when the muscle is relaxed."

After describing the air bladder, and the arrangement of its paired extrinsic muscles in *Platystoma orbignyanum*, and *Pseud-aroides clarias*, Dr. Sörensen continues (p. 93) :—" When the swim-bladder is laid open in the living animal, it is very easy to perceive that the contractions of the previously mentioned muscles [extrinsic muscles] occur at the same time as the production of a strong, deep, murmuring sound, whilst the wall of the swim-bladder is put into strong vibratory motion. The majority of the specimens I have examined of Pseudaroides had at the most a total length of 25—35 cm. The walls of the swim-bladder were, therefore, not so thick, but I was able to distinguish the internal transverse septa as darker transverse lines; I could therefore see very distinctly that when the sounds were produced, the septa were in a state of rapid vibration forwards and backwards. This is sufficient to prove that they play a very important part in tending to increase the sounds by the fact that the air vibrates over their free edges, from one chamber to the other. If one makes a small hole in the swim-bladder of Platystoma, the strength of the sounds will not be very much diminished. If an even smaller incision is made the sound becomes fainter and fainter, and at length dies away, even though the muscles are functional."

" So far as I have been able to see, only one muscular contraction takes place, as in Doras, for every time sound is produced. This always lasts a certain period, is fainter at the end, but ceases suddenly. About the nature of the sound, the same can be said as I have stated about Doras. The sound a Platystoma produces can be heard at a distance of more than 20 feet, when the animal is on the land."

From these observations it is also clear that the sounds produced by these fishes are not caused by the expulsion of air through the ductus pneumaticus, as erroneously assumed by us on pp. 298 and p. 301 of our memoir, but are caused by the vibration of the air within the air-bladder, which is set in motion either by the "elastic spring" apparatus, or by the extrinsic muscles.

The investigations of Dr. Sörensen seem to show that, under certain conditions, the "elastic spring" mechanism, and the paired extrinsic muscles of the *Pimelodinæ*, are structures subordinate to sound production, and are not, as we suggested, related to any method of adjustment to varying hydrostatic pressures. Had we appreciated this fact earlier, we should have modified certain of the tentative conclusions suggested on pp. 298—301 of our memoir. On the present occasion we wish to draw the attention of those interested in the subject to Dr. Sörensen's researches, and at the same time to express our regret at the injustice we have unintentionally done him.

The Society adjourned over Ascension Day to Thursday, May 10.

Presents, April 26, 1894.

Transactions.

Buitenzorg:—Jardin Botanique. Annales. Vol. XII. Partie 1. 8vo. *Leide* 1894. The Director.

Edinburgh:—Botanical Society. Transactions and Proceedings. Vol. XIX. Pages 233–636. 8vo. *Edinburgh* 1893. The Society.

Haarlem.—Musée Teyler. Archives. Vol. IV. Partie 2. 8vo. *Haarlem* 1894. The Museum.

Irkutsk:—East Siberian Section, Imperial Russian Geographical Society. Annual Report. 1892. [*Russian.*] 8vo. *Irkutsk* 1894. The Society.

Kazan:—Imperial University. Scientific Notes. [*Russian.*] 1894. No. 4. 8vo. *Kazan.* The University.

Kew:—Royal Gardens. Bulletin of Miscellaneous Information. 1894. No. 88. 8vo. *London.* The Director.

London:—Aristotelian Society for the Systematic Study of Philosophy. Proceedings. Vol. II. No. 3. Part I. 8vo. *London* 1894. The Society.

City and Guilds of London Institute. Report to the Governors, 1894. 8vo. *London.* The Institute.

Marine Biological Association. Journal. Vol. III. No. 2. 8vo. *London* 1894. The Association.

Marseilles:—Faculté des Sciences. Annales. Tome III. Fasc. 4. 4to. [*Marseille*·1893.] The Faculty.

Transactions (*continued*).

Paris:—École des Hautes Études. Bibliothèque. Fasc. 97, 99. 8vo. *Paris* 1893–94. The School.

Société Géologique. Bulletin. Vol. XXI. No. 4. 8vo. *Paris* 1893. The Society.

Pisa:—Società Toscana di Scienze Naturali. Atti. Vol. XIII. 8vo. *Pisa* 1894; Processi Verbali. Vol. IX. Pages 1—62 8vo. *Pisa* 1894. The Society.

Prague:—Gesellschaft zur Förderung Deutscher Wissenschaft, Kunst und Literatur in Böhmen. Mittheilung. Nr. 1. 8vo. *Prag* 1894. The Society.

St. Petersburg:—Kais. Akademie der Wissenschaften. Repertorium für Meteorologie. Bd. XVI. 4to. *St. Petersburg* 1893. The Academy.

Siena:—R. Accademia dei Fisiocritici. Atti. Vol. II. Fasc. 5—6. Vol. IV. Fasc. 9—10. Vol. VI. Fasc. 2—3. 8vo. *Siena* 1890-94. The Academy.

Somerville, Mass:—Tufts College. Studies. No. 1. 8vo. [*Somerville*] 1894. The College.

Toulouse:—Académie des Sciences, Inscriptions et Belles-Lettres. Mémoires. Tome V. 8vo. *Toulouse* 1893. The Academy.

Observations and Reports.

Batavia:—Magnetical and Meteorological Observatory. Observations. 1892. Folio. *Batavia* 1893; Rainfall in the East Indian Archipelago. 1892. 8vo. *Batavia* 1893.
The Observatory.

Bucharest:—Institutul Meteorologic. Analele. Tom. VII. 4to. *Bucuresti* 1893. The Institute.

France:—Service des Topographies Souterraines. Études des Gîtes Minéraux de la France. Bassin Houillier et Permien d'Autun et d'Épinac. Fasc. 5. 4to. *Paris* 1893. The Service.

India:—Great Trigonometrical Survey of India. Account of the Operations. Vol. XV. 4to. *Dehra Dun* 1893.
Secretary of State for India.

Mersey:—Report on the Present State of the River Mersey. 1893. 8vo. *London* 1894. Adm. Sir G. H. Richards, F.R.S.

Paris:—Bureau des Longitudes. Connaissance des Temps. 1896. 8vo. *Paris* 1893; Extrait de la Connaissance des Temps. 1895. 8vo. *Paris* 1893; Éphémérides des Étoiles de Culmination Lunaire et de Longitude. 1894. 4to. *Paris* 1893.
The Bureau.

Bureau International des Poids et Mesures. Travaux et Mémoires. Tome X. 4to. *Paris* 1894. The Bureau.

Observations and Reports (*continued*).

Sydney:—Department of Agriculture. Host and Habitat Index of the Australian Fungi. 8vo. *Sydney* 1893.

Mr. N. A. Cobb.

Trieste:—Osservatorio Astronomico-Meteorologico. Rapporto Annuale. 1891. 4to. *Trieste* 1894. The Observatory.

Journals.

American Journal of Philology. Vol. XV. No. 1. 8vo. *Baltimore* 1894. The Editor.

Archives Cliniques de Bordeaux. Année III. No. 3. 8vo. *Bordeaux* 1894. The Editors.

Astronomical Journal. Vol. XIV. No. 2. 4to. *Boston, Mass.* 1894. Smithsonian Institution.

Astronomy and Astro-Physics. February—April, 1894. 8vo. *Northfield, Minn.* The Editors.

Blue Book of Amateur Photographers. 1893. 8vo. *London.*

The Editor.

Alcock (A.) Natural History Notes from H.M. Indian Marine Survey Steamer "Investigator." Series II. No. 1. On the Results of Deep Sea Dredging during the Season 1890–91 (*cont.*). 8vo. [*London*] 1894. The Author.

Bruder (G.) Die Gegend um Saaz in ihren geologischen Verhält-nissen geschildert. 8vo. *Saaz* 1893.

Gesellschaft zur Förderung Deutscher Wissenschaft, Prague.

Caruel (T.) Flora Italiana. Vol. X. 8vo. *Firenze* 1894.

The Author.

Dawson (G. M.), F.R.S. Geological Notes on some of the Coasts and Islands of Bering Sea and Vicinity. 8vo. *Rochester* (*U.S.A.*) 1894; [And two other Excerpts. 8vo.]

The Author.

Kantor (S.) Premiers Fondements pour une Théorie des Trans-formations Périodiques Univoques. Folio. *Naples* 1891.

The Author.

Lewis (Henry Carvill) Papers and Notes on the Glacial Geology of Great Britain and Ireland. Edited by H. W. Crosskey. 8vo. *London* 1894. Mrs. Carvill Lewis.

Bronze Copy of Medal, ' Analyse des Protubérances Solaires, 18 Août, 1868,' struck in honour of MM. Janssen and Lockyer.

M. Janssen, For. Mem. R.S., and Professor J. Norman Lockyer, F.R.S.

THE CROONIAN LECTURE.—"La fine Structure des Centres Nerveux." By SANTIAGO RAMÓN Y CAJAL, Professor of Histology, University of Madrid. Received March 1,— Read March 8, 1894.

A l'invitation gracieuse que m'ont faite les honorables membres de cette société savante de venir dans cette séance rendre compte de mes travaux sur la structure des centres nerveux, mon premier dessein, je ne le cacherai pas, a été de renoncer à un honneur que je jugeais par trop disproportionné avec mes mérites ; mais je songeai ensuite que votre bienveillance à m'écouter ne saurait être moindre que la générosité de votre invitation, et je me suis résigné au rôle, peu flatteur du reste, d'interrompre un moment l'harmonieux concert de vos beaux travaux. J'ai d'autant plus besoin de toute votre indulgence que je vais vous entretenir d'un sujet qui vous est parfaitement connu. Tout ce que je vais vous dire, des maîtres aussi éminents que His, Kölliker, Waldeyer, von Lenhossék, van Gehuchten, l'ont déjà publié et résumé d'une manière presque irréprochable. Je vais essayer cependant de vous donner, moi aussi, un aperçu de la structure du système nerveux central, et pour cela je m'inspirerai surtout, comme on m'en a prié, de mes propres recherches.

Les centres nerveux des mammifères, spécialement ceux de l'homme, représentent le véritable chef-d'œuvre de la nature, la machine la plus subtilement compliquée que la vie puisse nous offrir. En dépit de cette complication, capable de décourager les esprits les plus hardis, il n'a pourtant jamais manqué de patients anatomistes qui, utilisant la technique de leur époque, ont tenté de débrouiller la trame délicate de l'axe encéphalo-spinal. Ils étaient guidés, cela ne fait point de doute, par l'espoir que la découverte de la clef structurale des centres nerveux jetterait une vive lumière sur les importantes activités de ces organes. Les premières données positives, quoique incomplètes, relatives à la fine anatomie des substances grise et blanche, nous les devons à Ehrenberg, qui en 1833 découvrit les fibres nerveuses, à Rémak, à Hannover, à Helmholtz, à Wagner, qui, à la même époque, ou quelques années plus tard, trouvèrent les corpuscules multipolaires et crurent que ces expansions ramifiées des cellules étaient en continuation avec les fibres nerveuses. En 1865 Deiters, un des plus sagaces observateurs que l'anatomie ait jamais eus, nous fit faire un grand pas dans la connaissance de la morphologie de la cellule nerveuse ; il démontra que dans toute cellule nerveuse il y avait toujours des expansions de deux sortes, c'est-à-dire que, outre les expansions ramifiées ou protoplasmiques, il s'en trouve une autre non ramifiée, ou cylindre-axe, se continuant directement avec un tube

nerveux. Cette découverte importante était déjà préparée par les travaux de Wagner, qui en 1847 avait appelé l'attention des savants sur l'existence de deux sortes de prolongements dans les cellules de l'encéphale de la torpille, et par Rémak, qui en 1854 retrouva dans la moelle épinière du bœuf une disposition semblable.

Les travaux de Gerlach étendirent encore les notions apportées par Deiters. Ils servirent de fondement, ainsi que vous le savez, à une conception théorique de la structure de la substance grise qui a regné dans la science presque jusqu'à nos jours. Gerlach imaginait que les expansions nerveuses des cellules de la corne anté- rieure de la moelle se continuent avec les racines motrices, tandis que les racines sensitives tirent leur origine d'un réseau nerveux inter- stitiel formé par les anastomoses des expansions protoplasmiques.

Je n'insisterai pas davantage sur cette conception, pas plus que sur les déductions physiologiques que l'on en a fait découler. Qu'il me suffise de vous dire que la théorie du réseau protoplasmique interstitiel est une hypothèse anatomique qui ne s'appuie sur aucun fait positif d'observation. Il faut savoir en effet que les méthodes utilisées par Gerlach et ses successeurs pour établir la théorie du réseau inter- stitiel—coupes fines en série, coloriées au carmin, à l'hématoxyline, à la nigrosine ou au chlorure d'or—sont absolument inaptes à faire résoudre un problème de cette difficulté, et ne permettent de découvrir dans la substance grise qu'un plexus pâle, très compliqué, dans lequel il serait téméraire de supposer un mode quelconque de terminaison des fibres.

Quant aux méthodes plus modernes de Weigert-Pal, de Freud, et aux méthodes basées sur les dégénerations secondaires, créées par Charcot, Gudden, Türk, Bouchard, elles ne peuvent que nous montrer le trajet des fibres à myéline et la situation des stations cellulaires auxquelles elles sont reliées; elles ne sont en aucune façon à même de nous instruire sur le mode d'union des cellules et des fibres ou des cellules entre elles.

Sur ces entrefaites, un savant italien d'un grand mérite, bien connu pour sa découverte des organes terminaux musculo- tendineux et par la lumière qu'il a projetée dans la biologie du *plasmodium malariœ,* Camillo Golgi, annonça dès 1875 une méthode de coloration qui permit de teindre et d'observer parfaitement les plus fines expansions nerveuses, méthode qui faisait espérer une solu- tion prochaine et définitive du difficile problème des connexions intercellulaires. Cette méthode, dans son essence, consiste à soumettre à l'action du nitrate d'argent des morceaux de centres nerveux préa- lablement durcis dans le bichromate de potasse ou dans un mélange de liquidé de Müller et d'acide osmique. Sous l'influence du bain d'argent il se forme un précipité rouge, opaque, de chromate d'argent qui se dépose exclusivement dans l'épaisseur de quelques cellules et

fibres. Celles-ci ressortent alors d'une façon très nette et presque schématique sur un fond jaunâtre transparent. Grâce à cette importante innovation dans la technique microscopique M. Golgi put mettre en évidence les faits suivants :—

Primo, les expansions protoplasmiques des cellules nerveuses se terminent librement dans l'épaisseur de la substance grise.

Secundo, les prolongements fonctionnels des corpuscules nerveux émettent pendant leur trajet à travers la substance grise des ramilles collatérales très fines et ramifiées à plusieurs reprises.

Troisièmement, en ce qui concerne la façon dont se comportent les prolongements fonctionnels, on peut distinguer deux espèces de cellules : un type *moteur* caractérisé par la présence d'un cylindre axe qui ne perd pas son individualité et se continue avec une fibre de la substance blanche ; un type *sensitif*, caractérisé par l'existence d'un cylindre-axe qui, se divisant un très grand nombre de fois et presque dès son origine dans la substance grise, voit son individualité disparaître sans qu'il soit sorti de la substance grise même.

En quatrième lieu, il existe dans le sein de cette substance un réseau de fibres formé par les ramifications et les anastomoses des trois espèces de fibres nerveuses suivantes : les ramilles terminales des tubes nerveux centripètes ou sensitifs, les branches de l'arborisation terminale des cylindres-axes des corpuscules du type sensitif et les collatérales des expansions nerveuses des corpuscules du type moteur.

Enfin M. Golgi crut pouvoir énoncer à l'aide de ses observations que les prolongements protoplasmiques jouent un rôle de nutrition, puisqu'ils se mettent de préférence en rapport avec les vaisseaux et les cellules de la neuroglie.

Les recherches que nous avons entreprises durant ces cinq dernières années sur la structure de presque tous les centres nerveux, cervelet, moelle épinière, cerveau, bulbe olfactif, ganglions sympathiques, centres optiques, rétine, etc., si elles nous ont permis de confirmer en grande partie les faits annoncés par Golgi, nous ont porté en même temps à substituer aux trois hypothèses anatomo-physiologiques du savant italien, l'existence d'un réseau nerveux interstitiel, distinction des cellules en sensitives et motrices et rôle nutritif des prolongements protoplasmiques, par les propositions suivantes que nous considérons comme complètement démontrés.

Les cylindres-axes, de même que les expansions protoplasmiques, se terminent dans l'épaisseur de la substance grise par des ramilles parfaitement libres.

Les prolongements protoplasmiques, ainsi que le corps des cellules nerveuses, peuvent servir à la conduction des courants nerveux.

Les deux types physiologiques des cellules nerveuses admis par Golgi n'ont précisément pas de réalité physiologique ou fonctionnelle. Leur réalité morphologique est au contraire hors de doute. En effet, dans

la substance grise, à côté des éléments que nous avons nommés cellules à cylindre-axe court et dont le prolongement cylindraxile se résout en une arborisation terminale autour des corpuscules voisins, on en rencontre d'autres que nous appelons cellules à cylindre-axe long, dont l'expansion fonctionnelle se continue avec une fibre de la substance blanche. Or ces derniers, les corpuscules à cylindre-axe long, abondent dans des organes essentiellement, indubitablement sensitifs, comme la rétine, le bulbe olfactif; d'où la conclusion qu'ils ne jouissent pas d'une manière nécessaire et exclusive d'un rôle moteur.

La même circonstance et le même raisonnement s'appliquent aux corpuscules à cylindre-axe court; on ne peut réellement pas les considérer comme des cellules sensitives puisqu'ils se trouvent indistinctement dans tous les centres nerveux, tels que cerveau, cervelet, corps strié, rétine, bulbe olfactif, etc.

Les connexions établies entre les fibres et les cellules nerveuses ont lieu au moyen de contacts, c'est-à-dire à l'aide d'une véritable articulation entre les arborisations variqueuses des cylindres-axes d'un côté, le corps et les prolongements protoplasmiques de l'autre. Aussi est-on amené à se représenter l'axe encéphalo-spinal comme un édifice composé d'unités nerveuses superposées, de *neurones*, suivant l'expression de Waldeyer.

Au point de vue morphologique nos recherches nous ont appris d'autres faits de quelque importance.

Les expansions fonctionnelles des cellules nerveuses peuvent se diviser en T à leur arrivée dans la substance blanche, en produisant ainsi deux ou un plus grand nombre de tubes nerveux à myéline.

Les tubes nerveux de la substance blanche du cerveau, comme ceux de la substance blanche de la moelle épinière, du bulbe olfactif, de la corne d'Ammon, les fibres du cordon du grand sympathique, etc., émettent à angle droit des ramilles collatérales destinées à se ramifier et à se terminer librement dans l'épaisseur de la substance grise immédiate. Ces collatérales, que Golgi avait déjà mentionnées sommairement dans la moelle épinière, constituent une grande partie des commissures des organes nerveux centraux, commissure antérieure et postérieure de la moelle, corps calleux, commissure de la corne d'Ammon, etc., et presque la totalité du plexus serré des fibrilles qui entourent les corpuscules nerveux.

Reste enfin à examiner la question si capitale de la terminaison des cylindres-axes dans la substance grise. Déjà, depuis 1886, MM. His et Forel, soutiennent, à l'encontre des auteurs anciens, de Gerlach, et de Golgi lui-même, que les cylindres-axes se terminent dans cette substance non en formant des réseaux, mais uniquement par des extrémités libres.

Voici, brièvement rapportées, les raisons que M. His, dans un travail récent, allégea contre la théorie des réseaux. "L'embryologie démontre

que les fibres nerveuses représentent la continuation des expansions
des neuroblastes, chaque fibre doit, donc, pendant une longue
période de son développement, avancer librement.   On ne voit pas
pourquoi cette disposition se modifierait ultérieurement.   Nous con-
naissons, en outre et depuis longtemps, une série de terminaisons
nerveuses tout à fait libres ; aussi celles des muscles, de la cornée, de
la peau, des corpuscules de Pacini, etc., qui se font tantôt par une
extrémité arrondie et épaisse, tantôt par une arborisation nerveuse
complètement libre.   Il nous semble donc peu raisonnable d'admettre
une distinction fondamentale entre les terminaisons périphériques et
les terminaisons centrales."

Pour Forel, sa négation des réseaux se base sur ce qu'il n'est
jamais parvenu à reconnaître des anastomoses de fibrilles nerveuses
dans les coupes de substance grise imprégnées par la méthode de
Golgi.

Ce sont là des arguments de haute portée en faveur de l'indépen-
dance absolue des corpuscules nerveux ; et pourtant la plupart des
neurologistes resta fidèle à la vieille doctrine.   C'est que, pour
trancher définitivement cette question il fallait en effet ne pas se
contenter d'arguments négatifs ou de raisonnements par analogie ; il
fallait faire la preuve certaine, absolue, irréfutable des dernières rami-
fications des cylindres-axes et de leurs collatérales dans la substance
grise et résoudre, du même coup, le problème des connexions intercel-
lulaires.   C'est là l'œuvre que nous croyons avoir accomplie en
employant sur les parties nerveuses en voie d'évolution, ou très proches
de leur développement complet, la méthode de Golgi quelque peu
modifiée.   Dans une série de travaux ayant pour objet la moelle, le
cervelet, le cerveau, la rétine, le grand sympathique, etc., nous sommes
arrivé à démontrer, sans laisser prise au moindre doute, les arborisa-
tions nerveuses terminales qui siègent autour des cellules de ces organes ;
et les recherches ultérieures de Kölliker, van Gehuchten, His,
Waldeyer, Edinger, von Lenhossék, A. Sala, P. Ramon, G. Retzius,
etc., n'ont fait que confirmer l'existence de cette disposition terminale,
tout en ajoutant d'importantes découvertes.   C'est à Retzius surtout
que nous sommes redevables des preuves les plus convaincantes, car
il a réussi à démontrer la terminaison libre des arborisations nerveuses,
non seulement dans l'axe cérébro-spinal des vertébrés, mais encore
dans les ganglions des invertébrés, crustacés, vers, etc., où il s'est
servi de la méthode d'Ehrlich au bleu de méthylène, dont les révéla-
tions coïncident complètement avec celles de la méthode de Golgi.

Les principes généraux de la morphologie et des connexions des
neurones étant ainsi exposés, nous allons maintenant passer succincte-
ment en revue les diverses modalités de rapports ou d'articulation
que présentent les éléments de quelques centres nerveux.

Voyons tout d'abord les racines sensitives et la moelle épinière.

Les recherches de Ranvier, de Retzius, de von Lenhossék nous ont appris que les cellules des ganglions rachidiens possèdent une seule expansion divisée en deux branches : *l'une externe*, généralement plus épaisse, qui se dirige vers la périphérie pour se terminer dans la peau ou dans un corpuscule sensitif ; *l'autre interne*, qui pénètre dans la racine sensitive ou postérieure pour se rendre à la moelle épinière. Cette dernière branche, d'après nos observations chez les oiseaux et chez les mammifères, ne pénètre pas directement dans la substance grise, mais se bifurque dans l'épaisseur du cordon postérieur, de façon à donner une branche ascendante et une branche descendante (fig. 1). Cette bifurcation à la forme d'un Y et les fibres qui en résultent se portent le long du cordon postérieur pendant un trajet indéterminable, mais qu'on peut évaluer à plusieurs centimètres ; leur terminaison a lieu dans lè sein de la substance grise, au moyen d'arborisations variqueuses et péricollulaires.

Mais outre ces arborisations terminales, dont l'imprégnation est souvent difficile, les fibres radiculaires sensitives possèdent un nombre infini de ramilles collatérales, partant à angle droit, soit de la tige, soit des branches ascendantes et descendantes, grâce auxquelles elles se mettent en rapport de contiguité avec les cellules de la substance grise. Dans ces collatérales on peut en distinguer de longues, ou destinées à la corne antérieure, et de courtes, ou destinées à la corne postérieure.

Les *collatérales courtes* traversent, réunies en faisceaux méridiens, la substance de Rolando, et se résolvent en arborisations variqueuses fort compliquées qui entourent les cellules de la colonne de Clarke, ainsi que celles dont le siége est dans la tête de la corne postérieure.

Les *collatérales longues* constituent un faisceaux antéro-postérieur fort épais qui, traversant la corne postérieure, se dissémine dans le sein de la corne antérieure (fig. 2). Ces collatérales fournissent un grand nombre de ramifications, dont la plupart se terminent eu se mettant en contact avec le corps ou les expansions protoplasmiques des cellules motrices. Étant donné que les longues collatérales représentent le seul moyen de communication entre les racines sensitives et les cellules de la corne antérieure, il faut les considérer comme la voie ordinaire des reflexes. C'est pourquoi on appelle actuellement ces collatérales fibres *reflexo-motrices*, à l'exemple de Kölliker, ou fibres *sensitivo-motrices*, nom que je leur ai attribué. D'après quelques recherches que nous avons entreprises très récemment chez l'embryon du poulet, les collatérales longues partent non de tout le trajet vertical des branches ascendante et descendante, mais, de préférence, de la portion voisine de la bifurcation. Sur le reste de leur parcours les branches de bifurcation donnent surtout naissance aux collatérales courtes.

Toutes les fibres de la racine postérieure ne se bifurquent pas dans

FIG. 1. Schème des rapports entre les cellules des ganglions rachidiens et les corpuscules moteurs de la corne antérieure. A, Cellule du ganglion rachidien ; B, bifurcation des fibres de la racine postérieure ; C, collatérales longues se mettant en relation avec les cellules de la corne antérieure ; D, cellules radiculaires ; E, fibre de la racine antérieure.

Nota.—Les flèches indiquent le sens probable des courants nerveux et les rapports dynamiques des diverses cellules.

la substance blanche ; Lenhossék et nous-même avons reconnu qu'il existe aussi un petit groupe de radiculaires centrifuges dont les cellules d'origine se trouvent dans la corne antérieure.

Le rôle de ces collatérales sensitives est considérable ; elles étab-

FIG. 2. Schème de la moelle épinière et des ganglions sensitifs et sympathiques. A, cellules radiculaires; B, cellule radiculaire dont le cylindre-axe marche à la racine postérieure; C, racine motrice; D, racine sensitive; E, ganglion rachidien; F, ganglion sympathique; G, *ramus communicans*; H, branche postérieure du pair rachidien; I, branche antérieure de celui-ci; *a*, collatérales longues s'étendant jusqu'à la corne antérieure; *b*, collatérales courtes se dirigeant à la colonne de Clarke; *c*, cellule dont le cylindre-axe semble aller à la voie cérébelleuse; *e*, fibre de la racine antérieure; *f*, cylindre-axe sympathique qui donne origine à une ramille pénétrant dans la racine antérieure; *g*, fibre de la racine antérieure semblant se terminer dans le ganglion sympathique; *h*, fibre sympathique dans le *ramus communicans*, et allant à la périphérie.

lissent des rapports de contact avec presque tous les corpuscules de la substance grise dont nous allons nous occuper.

Les corpuscules de la substance grise de la moelle peuvent être classés sous quatre dénominations : primo, les *cellules commissurales*, c'est-à-dire dont le prolongement cylindraxile contribue à former la commissure antérieure en se rendant au cordon antéro-latéral de l'autre côté; secundo, les *cellules des cordons*, ou dont le cylindre-axe se

continue, soit par simple inflexion à angle droit, soit au moyen d'une bifurcation en T avec une fibre de la substance blanche du même côté (cordon antérieur, latéral et postérieur) ; tertio, les *cellules radiculaires* ou motrices, dont l'expansion fonctionnelle constitue les racines antérieures ; quarto, les *cellules pluricordonales*, ou à cylindre-axe complexe, dont l'expansion nerveuse, d'abord simple, fournit deux, trois ou un plus grand nombre de tubes pour les cordons d'un côté ou les cordons des deux côtés.

Le temps nous manquerait, certainement, pour étudier la marche probable de l'excitation sensitive à travers les cylindres-axes de tous ces éléments ; aussi nous bornerons-nous à la suivre dans deux voies dont l'interprétation nous semble la plus facile ; ce sont la voie *reflexo-motrice* et la voie cérébelleuse.

Amenée par les radiculaires postérieures, l'impression sensitive se divise au niveau des bifurcations de ces dernières en deux courants, ascendant et descendant. Si l'excitation est de faible intensité, elle peut dériver par les collatérales longues ou reflexo-motrices, qui naissent, comme nous venons de l'exposer, de la première portion du trajet des branches ascendante et descendante, ainsi que de la tige d'origine, et être transmise ensuite aux cellules motrices d'un segment limité de la corne antérieure ; mais si l'excitation est plus forte, outre les voies reflexo-motrices, elle suivra la totalité des branches ascendante et descendante, et tout le système des collatérales courtes sera par la suite influencé. Le mouvement parviendra de cette manière à la colonne de Clarke, région où se terminent plusieurs collatérales courtes, et, par l'intermédiaire des cylindres-axes des cellules siégeant dans cette colonne, il gagnera la voie cérébelleuse ascendante de la moelle.

Ajoutons encore que les collatérales courtes, ainsi que les arborisations terminales des branches ascendante et descendante des radiculaires sensitives, se mettent en rapport avec les cellules commissurales de la corne postérieure, dont les cylindres-axes vont soit au cordon antéro-latéral du côté opposé, soit au faisceau fondamental du cordon latéral du même côté, constituant là des voies courtes, en grande partie ascendantes, destinées vraisemblablement à porter l'ébranlement sensitif aux cellules motrices de segments plus éloignés de la moelle.

La propagation de l'impression sensitive jusqu'au cerveau exige encore l'admission de certains neurones intermédiaires que l'on appelle *cellules sensitives centrales.* Ces cellules siégeraient dans toutes les régions de la moelle et du bulbe où se terminent des fibres radiculaires sensitives ; leurs cylindres-axes auraient un cours ascendant, et s'achèveraient, après avoir croisé la ligne médiane, dans l'écorce cérébrale de l'autre côté. L'entrecroisement se ferait surtout à la partie inférieure de la moelle allongée, au niveau du ruban de Reil.

Mais, d'après van Gehuchten, il aurait lieu aussi tout le long de la moelle épinière, au niveau de la commissure antérieure.

Du reste, l'existence des cellules sensitives centrales est encore fort énigmatique. Dans la moelle épinière, outre la voie cérébelleuse, on ne peut distinguer, à l'aide des méthodes anatomiques, une voie ascendante spéciale destinée à recueillir les excitations sensitives apportées par les fibres radiculaires postérieures. Il y a cependant deux faits qui militent en faveur de l'existence d'une voie sensitive centrale; d'abord l'absence d'entrecroisement des fibres radiculaires sensitives et ensuite la circonstance que la plupart de ces dernières représentent des voies courtes, se terminant dans les divers segments de la moelle épinière.

Etudions ensemble les *connexions des fibres nerveuses olfactives* (fig. 3).

Nos recherches concordant avec celles d'Arstein, Grassi et Castronuovo, van Gehuchten, Brunn, nous montrent les cellules nerveuses bipolaires de la muqueuse olfactive émettant par leur extrémité profonde une fibrille variqueuse, ou prolongement cylindraxile, qui se continue avec un filament des nerfs olfactifs. Durant leur passage à travers le tissu conjonctif sous-épithélial ces filaments ne donnent pas de ramifications et conservent leur individualité; à leur arrivée au bulbe olfactif ils pénètrent dans l'épaisseur des glomérules, où ils se terminent au moyen d'une arborisation courte, variqueuse et parfaitement libre.

Les couches constitutives du bulbe olfactif sont : la zone des fibres nerveuses olfactives, la zone des glomérules, la zone des cellules à panache protoplasmique et la zone des grains et des fibres nerveuses profondes.

La couche des cellules à panache est une des plus intéressantes, parce qu'elle renferme les éléments destinés à recueillir l'excitation olfactive. Ces éléments, qui varient dans leur forme et leur siége mais non dans leurs traits essentiels, se distinguent en ce qu'ils possèdent un cylindre-axe long qui se rend à la racine externe du bulbe olfactif, en ce qu'ils offrent des expansions protoplasmiques latérales s'étalant dans une couche d'aspect moléculaire, et, finalement, en ce qu'ils présentent un ou deux prolongements protoplasmiques périphériques épais, qui se terminent dans l'épaisseur des glomérules au moyen d'un élégant panache de ramilles courtes et fort variqueuses. Les glomérules eux-mêmes ne sont que le résultat de la juxtaposition et de l'entrelacement de deux espèces de fibres terminales : les ramilles variqueuses des fibres olfactives et les branches relativement robustes du panache protoplasmique que nous venons de mentionner. Entre ces deux espèces de ramifications il n'existe nulle anastomose, mais bien un contact très intime. Jamais on ne voit pénétrer dans les glomérules venant du bulbe olfactif d'autres fibres que les tiges à panache; on peut aussi affirmer que jamais aucune ramification des

Fig. 3. Schéma de l'ensemble des rapports des cellules de l'appareil olfactif. A, cellules bipolaires de la muqueuse olfactive; B, glomérules olfactifs; C, cellules mitrales; D, grain; E, moine externe du nerf olfactif; F, écorce grise de la région sphénoïdale du cerveau; a, petite cellule à panache; b, panache protoplasmique d'une cellule mitrale; c, panache épineux d'un grain; e, collatérales des fibres provenant des cellules mitrales; f, collatérales se terminant dans la couche moléculaire de l'écorce frontale et sphénoïdale; g, cellules triangulaires superficielles de l'écorce; h, cellules épithéliales de la muqueuse olfactive.

fibres olfactives n'émerge du glomérule. Une pareille disposition nous donne donc à considérer deux faits dont l'importance n'échappera à personne. D'abord les expansions protoplasmiques ont un rôle conducteur, car elles constituent des anneaux de la chaîne des neurones olfactifs; ensuite, la transmission s'opère par des contacts entre les ramifications nerveuses et les arborisations protoplasmiques.

Pour abréger, indiquons rapidement le chemin suivi par l'excitation olfactive. Elle traverse successivement les cellules bipolaires de la muqueuse, les cylindres-axes de celle-ci constituant les fibres du nerf olfactif; les cellules à panache du bulbe, les cylindres-axes de ces dernières se réunissant pour former la racine externe du bulbe; elle aboutit finalement aux corpuscules pyramidaux de l'écorce cérébrale frontale et sphénoïdale où les cylindres-axes des cellules mitrales envoient leurs arborisations libres.

A propos de la terminaison des fibres de la racine externe nous devons fixer l'attention sur un fait de quelque intérêt. Ces fibres, d'après les résultats de mes recherches et de celles de M. Calleja, fournissent exclusivement leurs arborisations terminales, ainsi qu'un grand nombre de ramifications collatérales, à la première couche cérébrale ou zone moléculaire, de sorte que l'excitation olfactive est reçue seulement par le panache périphérique de la tige des pyramides. Nous reviendrons bientôt sur ce fait, qu'on peut observer aussi dans le lobe optique des oiseaux, au niveau des terminaisons des fibres optiques; cela semble indiquer que la zone moléculaire est l'endroit où s'établit la transformation du courant sensitif conscient qui y arrive en impulsion motrice volontaire qui en part.

Les *connexions des fibres visuelles et des cellules de la rétine* (fig. 4) vont à leur tour nous apprendre une série de faits d'une haute signification.

On peut, malgré sa complication, considérer la rétine comme un ganglion nerveux formé par trois rangées de neurones ou de corpuscules nerveux; la première rangée renferme les cônes et les bâtonnets avec leurs prolongements descendants formant la couche des grains externes; la seconde est constituée par les cellules bipolaires, et la troisième est due à la réunion des corpuscules ganglionnaires. Ces trois séries d'éléments s'articulent au niveau des couches dites moléculaires ou réticulaires et internes.

La couche moléculaire externe de la rétine renferme une articulation multiple dont les éléments sont : en dehors, les sphérules terminales de la fibre des bâtonnets et les pieds coniques munis d'excroissances filamenteuses latérales, des fibres des cônes; en dedans, les panaches externes ou prolongements périphériques des cellules bipolaires, dont il existe deux espèces : les bipolaires à panache aplati, ou destinées aux cônes, et les bipolaires à panache ascendant, ou destinées aux bâtonnets; les ramilles protoplasmiques et les arborisations nerveuses

Fig. 4. Schéma de l'ensemble des rapports des cellules de l'appareil visuel. A, cônes de la région de la *fovea centralis*; B, grains externes de cette région; C, articulation entre les bipolaires et les cônes; D, articulation entre les cellules bipolaires et les cellules ganglionnaires. a et b, cônes et bâtonnets des autres regions de la rétine; c, bipolaire destinée aux cônes; d, bipolaire destinée aux bâtonnets; e, cellules ganglionnaires; f, spongioblaste; g, fibre centrifuge; h, nerf optique; i, arborisations terminales des fibres optiques dans les corps genouillé; j, cellules qui reçoivent l'impression visuelle; m, cellules desquelles partent probablement les fibres centrifuges.

de certaines cellules horizontales constituant les cellules étoilées ou sous-réticulaires de quelques auteurs.

La *couche moléculaire interne* renferme une articulation encore plus compliquée, que l'on pourrait décomposer en trois ou un plus grand nombre d'étages. Les facteurs principaux sont représentés, en dehors, par les panaches terminaux variqueux du prolongement descendant des bipolaires et les ramifications terminales des spongioblastes; en dedans, par les arborisations protoplasmiques aplaties des cellules de la couche ganglionnaire.

Abstraction faite de certains elements dont le rôle est encore très obscur, comme les spongioblastes et les cellules horizontales, voici les neurones qui participent à la transmission visuelle: les cônes et les bâtonnets, les cellules bipolaires, les cellules ganglionnaires et les fibres du nerf optique, les cellules; fusiformes et pyramidales des corps genouillés et des tubercules quadrijumeaux. ·

Chez les oiseaux, où nous avons réussi à colorer très complètement les éléments du lobe optique, on reconnaît que les fibres optiques entourent d'abord cet organe, et qu'elles se terminent au moyen d'arborisations fort variqueuses, très riches et complètement libres. Ces ramifications, qui siégent dans les couches les plus périphériques du lobe optique, se mettent en contact avec les expansions proto-plasmiques externes de certaines cellules fusiformes dont les cylindres-axes pénètrent plus profondément. Chaque arborisation optique se met en relations avec un groupe de cellules; de cette façon l'excita-tion apportée par une fibre se dissémine dans l'épaisseur de la substance grise, le nombre des cellules et des cylindres-axes qui interviennent dans la conduction croissant à mesure que s'avance l'excitation visuelle.

Le nerf optique possède encore des fibres centrifuges qui se ter-minent par des arborisations libres très variqueuses autour des corps des spongioblastes de la rétine, auxquels elles apportent une excitation nerveuse d'origine centrale et dont la signification est actuellement indéterminée.

L'examen très succinct et par cela même aride que nous venons de faire de la marche des excitations sensitivo-sensorielles dans la rétine, le bulbe olfactif et la moelle, prouve non seulement que les expansions protoplasmiques remplissent un rôle conducteur, mais encore que le mouvement nerveux est dans ces expansions cellulipète, tandis qu'il est cellulifuge dans les cylindres-axes. En d'autres termes, la cellule nerveuse présente un appareil de *réception* des courants figuré par les expansions dendritiques et le corps cellulaire, un appareil de *trans-mission* représenté par le prolongement cylindraxile, et un appareil de *répartition* ou de *distribution* représenté par l'arborisation nerveuse terminale. Dans tous les organes où le sens des courants est suffisamment connu, comme la moelle, la voie pyramidale du cerveau,

le ganglion spiral du limaçon, les cellules sensitives cutanées des vers, d'après Lenhossék, cette orientation dynamique est aisée à vérifier.

Il est encore une autre induction qu'il nous semble légitime de tirer des faits que nous venons d'énumérer, c'est la diffusion croissante des courants à fur et à mesure qu'ils atteignent des organes plus centraux. Par exemple: l'excitation olfactive amenée aux glomérules par les fibres olfactives est conduite au cerveau par l'intermediaire de quelques cellules à panache—vous vous rappelez que l'on rencontre dans les glomérules un faisceau de fibres olfactives et un groupe de tiges de cellules à panache—et ce fait se répète dans la zone moléculaire du cerveau, où chaque fibre de la racine externe du nerf olfactif se met en contact, à l'aide de ramifications collatérales et terminales, avec une quantité considérable de panaches périphériques de pyramides. On peut en dire autant des excitations visuelles et des excitations sensitives de la moelle.

Voyons maintenant quels sont les *neurones et les connexions de ces neurones dans une lamelle de cervelet* (fig. 5). Une section transversale, par exemple, nous montrera trois couches concentriques de neurones.

La première, ou zone moléculaire, est formée principalement par les petites cellules étoilées superficielles. La seconde, ou intermédiaire, est constituée par les corps des cellules de Purkinje. La troisième résulte de l'agglomération des grains.

Tous ces éléments offrent deux espèces de rapports: des rapports intrinsèques, c'est-à-dire établis entre les cellules des trois couches; des connexions extrinsèques, c'est-à-dire ayant lieu entre les neurones du cervelet et des neurones appartenant à d'autres organes nerveux.

Examinons successivement les connexions intrinsèques et extrinsèques. D'abord les connexions des cellules de Purkinje avec les petits éléments étoilés de la couche moléculaire. Les rapports établis entre ces deux ordres de cellules constituent l'exemple le plus classique d'arborisations nerveuses péricellulaires, et le fait le plus éloquent de transmission par contact, par contiguité, de l'action nerveuse.

Les petits éléments étoilés de la couche moléculaire sont aplatis dans le même sens que les cellules de Purkinje; ils possèdent une ramification protoplasmique divergente, qui ne dépasse jamais l'épaisseur de la couche où ils sont renfermés, et un cylindre-axe horizontal dont le trajet est perpendiculaire à l'axe longitudinal des lamelles cérébelleuses. Ce prolongement cylindraxile émet plusieurs collatérales descendantes, et, après un parcours variable, décrit une courbe pour venir s'achever au niveau des corps des cellules de Purkinje, au moyen d'une arborisation très riche et variqueuse. Ces arborisations terminales, de même que les ramilles collatérales descendantes, se ramifient à plusieurs reprises et constituent autour des cellules de Purkinje un plexus très serré terminé en pointe de pinceau

FIG. 5. Schème des connexions des cellules de Purkinje du cervelet. A, cellules de Purkinje dont le corps apparaît entouré par les ramilles nerveuses provenant des prolongements cylindraxiles des petits corpuscules étoilés de la couche moléculaire; B, cylindre-axes de ces corpuscules; C, fibre grimpante; D, cylindre-axe d'une cellule de Purkinje; E, grains dont le cylindre-axe ascendant se bifurque dans la couche moléculaire; G, fibre moussue.

à la partie inférieure du corps de ces cellules, au niveau même de l'origine de leur cylindre-axe. Aussi avions-nous donné à cette disposition le nom de *pinceaux descendants*, auquel Kölliker, Retzius et les autres auteurs qui en ont confirmé l'existence préfèrent le terme de *corbeilles terminales.*

Comment ne pas considérer ces plexus péricellulaires comme un moyen de rapport entre les cellules étoilées de la couche moléculaire et les éléments de Purkinje? Et il faut bien le savoir, cette con-

nexion n'est pas individuelle ; elle est collective ; c'est-à-dire que chaque plexus péricellulaire renferme des ramifications provenant de plusieurs cellules étoilées.

Voyons à présent les *rapports entre les grains et les cellules de Purkinje*. Les grains du cervelet sont de petits éléments nerveux dont l'agglomération constitue presque exclusivement la couche granuleuse. Ils possèdent trois ou quatre appendices protoplasmiques très courts, ornés à leur extrémité d'une arborisation digitiforme, et un cylindre-axe d'une finesse extraordinaire. Celui-ci monte jusqu'à la zone moléculaire et s'y bifurque à différentes hauteurs, produisant ainsi une fibrille longitudinale qui parcourt parallèlement toute la lamelle cérébelleuse. Ces intéressantes fibrilles, que nous avons appelées *parallèles*, parce qu'elles sont disposées parallèlement à la direction des lamelles du cervelet, se mettent en contact très intime, durant leur trajet, avec les contours épineux des branches protoplasmiques des cellules de Purkinje. Comme chaque fibrille parallèle parcourt la longueur totale de la circonvolution cérébelleuse, et s'y termine par des extrémités libres et arrondies, il s'en suit qu'un seul grain peut agir sur une multitude de corpuscules de Purkinje. Il est aussi très probable que chacun de ces derniers est soumis à l'influence d'un nombre considérable de grains.

Les *rapports extrinsèques, ou entre les cellules du cervelet et celles d'autres centres nerveux*, ont été et sont encore des plus difficiles à établir. Ainsi que Golgi le démontra le premier, les cellules de Purkinje donnent naissance à des prolongements nerveux du type long dont la terminaison est ignorée, et, inversement, dans la substance grise du cervelet se terminent des cylindres-axes venant d'autres organes dont la situation est encore très problématique. Ce sont les *fibres moussues* et les *fibres grimpantes*.

Les fibres *moussues* sont de gros tubes médullaires qui se ramifient et se terminent dans la couche des grains, où ils se mettent en contact avec les expansions protoplasmiques de ces petits éléments au moyen de certaines excroissances ou efflorescences collatérales. Les dernières ramilles finissent par une varicosité ou une petite ramification en forme de rosace.

Les *fibres grimpantes* traversent la couche des grains, longent le corps des cellules de Purkinje et enveloppent la tige ascendante et les branches protoplasmiques principales de ces éléments d'une magnifique arborisation terminale allongée, tout à fait comparable à celle des fibres motrices sur les faisceaux musculaires.

Il résulte de ce que nous venons d'exposer que les grains et les cellules de Purkinje peuvent recevoir des actions nerveuses d'autres centres au moyen soit des fibres moussues, soit des fibres grimpantes ; tandis que les petites cellules étoilées de la couche moléculaire, ainsi que les gros éléments étoilés de la zone des grains appartenant

au second type des cellules de Golgi, semblent n'avoir aucune relation avec les fibres extrinsèques. C'est ce qui nous a déterminé à
qualifier ces deux dernières espèces de cellules de *corpuscules d'association*, car elles paraissent avoir pour rôle exclusif d'associer les
éléments de Purkinje, ou les grains, en un ensemble dynamique dont
la signification est actuellement indéchiffrable.

Le dernier sujet que nous avons intentionnellement laissé pour la
fin de cette conférence, à cause de son importance primordiale et des
déductions psycho-physiologiques qu'on en peut tirer, a trait aux
connexions de l'écorce cérébrale (fig. 6). Pour que vous vous représentiez d'une façon plus claire cette écorce cérébrale, nous la décomposerons schématiquement en trois couches fondamentales qui vont de
la périphérie au centre : une couche moléculaire, une couche des
grandes et des petites cellules pyramidales, enfin une couche des
corpuscules polymorphes.

La *couche moléculaire*, qui ne fait jamais défaut dans le cerveau des
vertébrés, est formé par un plexus fort compliqué dont les facteurs
principaux sont les panaches périphériques des cellules pyramidales, que
pour abréger nous appellerons pyramides, les arborisations nerveuses
terminales de certaines cellules de la couche des pyramides dont le
cylindre-axe est ascendant, les ramifications de certains corpuscules
autochtones. Ces derniers éléments, qui siègent dans l'épaisseur même
de la zone moléculaire, affectent une forme fuselée ou triangulaire et
la plupart de leurs expansions devenant horizontales se résolvent
en une quantité considérable de ramilles d'apparence nerveuse. On
pourrait comparer ces éléments aux spongioblastes de la rétine et
aux grains du bulbe olfactif parce qu'ils manquent aussi de différenciation en expansions protoplasmiques et nerveuses.

La *couche des pyramides*, la plus épaisse de l'écorce, renferme de
nombreuses rangées de cellules longues de forme pyramidale, dont
le volume s'accroît à mesure qu'on s'éloigne de la périphérie. Les
principales propriétés de ces éléments sont de posséder une tige protoplasmique radiale terminée dans la couche moléculaire par un
panache de fibres plus ou moins horizontales et hérissées d'appendices
épineux, d'émettre diverses expansions protoplasmiques latérales et
descendantes, ramifiées à plusieurs reprises ; et finalement de donner
naissance à un cylindre-axe descendant, continué dans la substance
blanche, soit par un tube de projection, soit par une fibre d'association, soit encore par une fibre calleuse ou commissurale transversale.

La dernière couche, ou *des cellules polymorphes*, renferme des corpuscules de forme variée, généralement allongée, parfois triangulaire
ou fusiforme, mais dont un des prolongements se dirige très souvent
vers la surface cérébrale. Du reste, cette expansion externe ou
radiale ne se résout pas en panache comme la tige des cellules pyra-

Fig. 6. Les principaux types cellulaires de l'écorce cérébrale des mammifères. A, cellule pyramidale à taille moyenne; B, cellule pyramidale géante; C, cellule polymorphe; D, cellule dont le cylindre-axe est ascendant; E, cellule de Golgi; F, cellule, spéciale de la couche moléculaire; G, fibre se terminant librement dans l'épaisseur de l'écorce; H, substance blanche; I, collatérale de la substance blanche.

midales et n'atteint pas la couche moléculaire. Quant au cylindre-axe, il pénètre dans la substance blanche, où il se comporte comme celui des cellules pyramidales.

À leur passage dans la substance grise tous les cylindres-axes des pyramides et des corpuscules polymorphes émettent un grand nombre de collatérales ramifiées, qui se terminent librement autour des cellules nerveuses, ainsi que nous l'avons reconnu chez les petits mammifères nouveaux-nés. L'ensemble des ramifications des collatérales engendre dans la substance grise et autour des cellules un plexus d'une complication extrême. Ce plexus reçoit encore des ramifications des ramilles collatérales venant des tubes de la substance blanche et des arborisations terminales des fibres calleuses et d'association.

Vous devinez à cette complexité inextricable de l'écorce cérébrale quelle obscurité enveloppe encore notre connaissance de ses connexions inter-cellulaires. La diffusion considérable des arborisations nerveuses terminales, le manque de séparation précise des rapports nerveux correspondant à chaque couche cellulaire, telles sont les causes de toutes les difficultés. Nous serons donc très sobres sur ce point, et nous nous bornerons seulement à indiquer les connexions qui semblent les mieux déterminées ou les plus probables.

Les connexions des cellules pyramidales de l'écorce peuvent être distinguées en *superficielles*, ou de la couche moléculaire, et en *profondes*, ou des couches sous-jacentes.

Au niveau de la zone moléculaire chaque panache protoplasmique des pyramides entre en contact avec un nombre presque infini de fibrilles nerveuses terminales. Ces fibrilles appartiennent aux catégories suivantes : aux arborisations terminales des fibres d'association, c'est-à-dire des fibres dont les cellules d'origine siègent dans l'écorce soit du même hémisphère, soit de l'hémisphère opposé ; aux arborisations nerveuses provenant des cellules spéciales placées dans les couches sous-jacentes, éléments dits à cylindre-axe ascendant, qu'ont décrits Martinotti, Retzius· et celui qui a l'honneur de vous parler ; aux arborisations terminales de certains corpuscules spéciaux siégeant dans la première couche cérébrale elle-même ; aux ramifications terminales de fibrilles collatérales provenant de la substance blanche, ou des couches profondes de la substance grise, et encore à bien d'autres arborisations terminales, dont l'énumération nous entraînerait trop loin.

On voit donc qu'au niveau de cette couche moléculaire chaque pyramide peut être influencée non-seulement par les cellules habitant la même région de l'écorce ; cellules à cylindre-axe ascendant, collatérales ascendantes, etc., mais aussi par celles qui résident dans d'autres lobes, soit du même côté, soit du côté opposé. Il est aussi probable, comme nous l'avons exposé il y a

quelques instants, lorsque nous avons étudié les rapports des fibres nerveuses olfactives, que la première couche cérébrale reçoit les dernières ramifications des fibres sensitives et sensorielles. De la sorte, le panache périphérique des pyramides serait le point où commencerait l'excitation motrice volontaire; de là elle se communiquerait au corps cellulaire pyramidal et aux fibres de projection constitutives de la voie pyramidale.

On peut admettre, en outre, que lorsqu'on excite électriquement l'écorce cérébrale d'un animal, des contractions musculaires se produisent, parce que le *stimulus* agit soit sur le panache des pyramides, soit sur les fibres nerveuses de la couche moléculaire, dont le rôle, à mon avis, serait d'apporter les courants aux panaches.

Quant aux connexions profondes, c'est-à-dire à celles qui ont lieu dans l'épaisseur même de la couche des pyramides et des cellules polymorphes, elles semblent avoir pour objet de rendre solidaires les éléments d'une rangée avec ceux des rangées sous-jacentes. Les facteurs de cette articulation nerveuse sont d'un côté le corps, la tige radiale et les branches basilaires des pyramides d'une série inférieure, et de l'autre, les collatérales nerveuses innombrables émanées des cylindres-axes des pyramides d'une série supérieure. Chacune de ces collatérales, grâce à ses nombreuses ramifications et à son étendue considérable, peut toucher et influencer des centaines de pyramides sous-jacentes.

Nous ne voulons pas prolonger davantage cette fastidieuse exposition des connexions inter-cellulaires de l'écorce cérébrale et nous allons terminer cette causerie par quelques considérations générales qui découlent de l'ensemble de nos recherches sur les centres nerveux.

D'une manière synthétique on peut dire que tout centre nerveux résulte de l'association des quatre parties suivantes: les cellules nerveuses à cylindre-axe court, c'est-à-dire ramifiées dans l'épaisseur même de la substance grise; les fibres nerveuses terminales arrivées d'autres centres ou de régions distantes du même centre; les cellules nerveuses à cylindre-axe long, c'est-à-dire prolongé jusqu'à la substance blanche; les collatérales qui naissent soit du trajet à travers la substance grise des prolongements cylindraxiles des cellules à expansion nerveuse longue, soit du cours des tubes de la substance blanche. Dans certains organes, tels que la rétine, le bulbe olfactif et la première couche cérébrale, il faut ajouter un cinquième facteur de structure; ce sont les éléments caractérisés par l'absence de différenciations en expansions nerveuses et protoplasmiques. Cela vous rappelle les grains du cervelet, les spongioblastes de la rétine et les cellules spéciales de l'écorce cérébrale.

Toute fibre nerveuse est la continuation de l'expansion fonctionnelle *d'une cellule* nerveuse. Cette loi se réalise aussi dans les *ganglions du grand* sympathique dont les éléments, d'après nos observations

confirmées par Retzius, van Gehuchten, L. Sala 'et von Lenhossék, offrent deux sortes de prolongements: des appendices ramifiés ou protoplasmiques qui se terminent librement dans le ganglion même, et un prolongement cylindraxile qui se continue avec une fibre de Rémak.

Les cellules nerveuses constituent des unités, les *neurones* de Waldeyer, dont les rapports réciproques consistent en véritables articulations. Les facteurs de chaque contact sont, d'une part, le corps et les expansions protoplasmiques des cellules, et, d'autre part, les arborisations terminales des fibres nerveuses.

Dans les organes où l'origine de l'excitation est bien établie on reconnaît que les cellules sont polarisées, c'est-à-dire que le courant nerveux pénètre toujours par l'appareil protoplasmique ou le corps cellulaire, et qu'il sort par le cylindre-axe qui le transmet à un nouvel appareil protoplasmique.

La differenciation compliquée de l'appareil protoplasmique—expansions basilaires, tige protoplasmique radiale, panache terminal, etc.—que nous présentent les pyramides du cerveau, et en partie aussi les corpuscules de Purkinje du cervelet, paraît avoir pour but de permettre que chacune des cellules de cette espèce puisse établir des contacts distincts avec diverses catégories de fibres nerveuses.

Les éléments qui, comme les spongioblastes de la rétine ou les corpuscules des ganglions spinaux, manquent d'appareil protoplasmique se mettent en relation avec une seule espèce de fibres nerveuses. Dans ces éléments l'appareil de réception est représenté par le corps protoplasmique seul.

On peut affirmer que plus sont nombreuses, ramifiées et différenciées les expansions protoplasmiques d'un élément, plus est grande la quantité de cellules dont il subit l'influence. De même, plus le prolongement nerveux d'une cellule acquiert d'étendue et de ramilles collatérales et terminales, plus est considérable le nombre des corpuscules auxquels il pourra adresser ses courants. A ce double point de vue—différenciation et abondance des expansions protoplasmiques, quantité énorme des ramilles nerveuses collatérales et terminales— aucun élément nerveux ne semble approcher, même de loin, de la pyramide cérébrale des mammifères.

Le résultat de nos recherches comparatives sur les propriétés de la pyramide cérébrale c'est que plus on descend dans l'échelle des vertébrés moins l'appareil protoplasmique apparaît différencié et moins sont nombreuses, longues et ramifiées les collatérales des cylindres-axes. Ainsi, chez les oiseaux la pyramide manque de tige radiale et de véritable panache externe; chez les reptiles la tige et le panache périphérique existent, mais les expansions basilaires et latérales sont encore absentes ou réduites seulement à un ou deux prolongements descendants; chez les poissons la cellule pyramidale fait défaut.

Une pareille gradation peut s'observer aussi dans les diverses classes de vertébrés relativement au nombre et aux ramifications des collatérales nerveuses.

D'ailleurs il n'est pas nécessaire de quitter la classe des mammifères pour observer des différences, parfois très considérables, relativement à la richesse des expansions protoplasmiques et des collatérales nerveuses des pyramides. Ainsi, tandis que chez la souris les prolongements basilaires sont courts et peu ramifiés, chez l'homme ils deviennent très nombreux, longs et très ramifiés; en outre, les collatérales nerveuses de la souris, ainsi que celles du rat, du lapin etc., se dichotomisent seulement une ou deux fois, tandis que chez l'homme ces mêmes collatérales, beaucoup plus nombreuses, se divisent quatre ou cinq fois en constituant des ramilles si longues qu'on ne peut les obtenir entières sur une seule coupe.

D'autre part, nos recherches sur le développement des cellules nerveuses embryonnaires ou neuroblastes de His nous ont montré qu'à fur et à mesure que l'écorce cérébrale s'accroît les expansions protoplasmiques et les collatérales des cylindres-axes des pyramides deviennent plus longues et plus divisées. D'abord, le prolongement cylindraxile de ces dernières manque de ramifications et se termine au moyen d'un renflement épineux que nous avons appelé *cône d'accroissement*; puis, du trajet du cylindre-axe poussent des ramilles collatérales courtes semblables à des épines, qui, en s'accroissant et en se divisant successivement, établissent des contacts avec un nombre chaque fois plus considérable de cellules nerveuses. Chez les fœtus à terme, ainsi que chez les enfants de quelques mois, les expansions protoplasmiques basilaires et les collatérales nerveuses sont encore très courtes et simples, et il est très probable que ce processus d'étirement des prolongements cellulaires se continue jusqu'à l'âge adulte.

Les faits d'observation que nous venons d'exposer sommairement, et qui sont d'une portée si considérable en soi, nous ont suggéré une hypothèse susceptible de faire comprendre mieux que toutes les autres, soit l'intelligence acquise à la suite d'une éducation mentale bien dirigée, soit l'intelligence héréditaire, soit les adaptations cérébrales professionnelles, soit encore la création de certaines aptitudes artistiques.

La gymnastique cérébrale n'est pas susceptible d'améliorer l'organisation du cerveau en augmentant le nombre de cellules, car, on le sait, les éléments nerveux ont perdu depuis l'époque embryonnaire la propriété de proliférer; mais on peut admettre comme une chose très vraisemblable que l'exercice mental suscite dans les régions cérébrales plus sollicitées un plus grand développment de l'appareil protoplasmique et du système des collatérales nerveuses. De la sorte, des associations déjà créées entre certains groupes de cellules se renforceraient notablement au moyen de la multiplication des ramilles

terminales des appendices protoplasmiques et des collatérales nerveuses ; mais, en outre, des connexions intercellulaires tout à fait nouvelles pourraient s'établir grâce à la néoformation de collatérales et d'expansions protoplasmiques.

Une objection se présente immédiatement à vos esprits : Comment, direz-vous, le volume du cerveau peut-il se maintenir invariable s'il y a multiplication et même néoformation de ramuscules terminaux d'appendices protoplasmiques et de collatérales nerveuses ?

Pour répondre à cette objection rien ne nous empêche d'admettre ou une diminution corrélative des corps cellulaires ou un tassement proportionnel des régions du cerveau dont les fonctions ne se rapportent pas directement à l'exercice de l'intelligence.

On expliquerait encore le talent de famille par la transmission héréditaire aux descendants immédiats ou éloignés (par atavisme) de cette organisation supérieure des connexions des cellules pyramidales.

Bien d'autres déductions sont permises ; ainsi, chez les hommes dont le talent, comme l'exemple nous en est fourni par Gambetta, coïncide avec un cerveau de petites dimensions, les cellules nerveuses seraient ou moins nombreuses, ou peut-être simplement plus petites, mais en revanche elles présenteraient un système fort compliqué d'associations protoplasmico-nerveuses. Au contraire, les cerveaux excessivement volumineux, si souvent associés à une intelligence inférieure et même à l'imbécillité, renfermeraient un plus grand nombre de cellules, mais alors les connexions de celles-ci seraient très imparfaites. C'est peut-être ce qui a lieu pour les gros cerveaux de la baleine et de l'éléphant.

Cette hypothèse anatomo-physiologique n'est pas originale en principe, car il ne manque pas de physiologistes et de psychologues qui aient cherché la caractéristique somatique de l'intelligence dans la richesse des associations cellulaires, mais elle a ceci de nouveau, qu'elle se base sur des faits positifs de structure et non sur de pures suppositions concernant l'agencement et les rapports des corpuscules nerveux.

Vis à vis de la théorie des réseaux celle des arborisations libres des expansions cellulaires susceptibles de s'accroître apparaît non seulement comme plus probable, mais aussi comme plus encourageante. Un réseau continu pré-établi—sorte de grillage de fils télégraphiques où ne peuvent se créer ni de nouvelles stations ni de nouvelles lignes—est quelque chose de rigide, d'immuable, d'immodifiable, qui heurte le sentiment que nous avons tous que l'organe de la pensée est, dans certaines limites, malléable et susceptible de perfection, surtout durant l'époque de son développement, au moyen d'une gymnastique mentale bien dirigée. Si nous ne craignions pas d'abuser des comparaisons, nous défendrions notre conception en disant que l'écorce cérébrale est pareille à un jardin peuplé

d'arbres innombrables, les cellules pyramidales, qui, grâce à une culture intelligente, peuvent multiplier leurs branches, enfoncer plus loin leurs racines, et produire des fleurs et des fruits chaque fois plus variés et exquis.

Du reste nous sommes très loin de croire que l'hypothèse que nous venons d'esquisser puisse à elle seule expliquer les grandes différences quantitatives et qualitatives que présente le travail cérébral chez les divers animaux et dans la même espèce animale. La morphologie de la cellule pyramidale n'est qu'une des conditions anatomiques de la pensée. Or cette morphologie spéciale ne suffira jamais à nous expliquer les énormes différences qui existent au point de vue fonctionnel entre la cellule pyramidale d'un lapin et celle d'un homme, ainsi qu'entre la cellule pyramidale de l'écorce cérébrale et le corpuscule étoilé de la moelle ou du grand sympathique. Aussi à notre avis est-il très probable qu'en outre de la complexité de leurs rapports les cellules pyramidales possèdent encore une structure intraprotoplasmique toute spéciale, et même perfectionnée dans les intelligences d'élite, structure qui n'existerait pas dans les corpuscules de la moelle ou des ganglions.

"On Rocks and Minerals collected by Mr. W. M. Conway in the Karakoram Himalayas." By Professor T. G. BONNEY, D.Sc., F.R.S., and Miss C. A. RAISIN, B.Sc. Received February 15,—Read April 19, 1894.

During his journey in the Karakoram Himalayas, Mr. W. M. Conway collected more than 300 specimens of rocks and minerals, which, however, were generally rather small. These were sent to us for examination at University College, London. Thin slices have been prepared of the specimens which promised to be the more interesting. Of the rest, the mineral composition was verified in cases of doubt by examining pulverised fragments under the microscope.

Since the detailed results of our examination, which practically form an annotated catalogue of the specimens, will be printed as an appendix to Mr. Conway's forthcoming volume,* we restrict ourselves in this paper to a summary of our work, and to a notice of a few specimens which appear to be of more than local interest.

(1.) *General Description.*

Commencing with the crystalline rocks, and with the most basic of these, we find one specimen of a dark green serpentine, containing

* Since this paper was read, the first or descriptive part of the work has been published ('Climbing and Exploration in the Karakoram-Himalayas'), which gives *the positions* of the localities mentioned herein.

small glittering crystals of bastite, brought from *débris* at foot of a slope at the village of Mapnun on the Burzil Pass. The rock has been evidently affected by pressure, and is practically identical with a type of serpentine rather common in the Alps.

Many varieties of diorite have been collected. Of these, some are almost hornblendites (see below), others are normal diorites varying from coarse to fine grained, others, again, are really hornblende-schists. In some of the last it is likely that the foliation (as we believe to be generally the case with the hornblende-schists of the Lizard and of Sark)* is the result of fluxional movements anterior to consolidation, while in others this structure is more probably due to pressure, and to consequent mineral changes subsequent to the first solidification of the rock.

Granites are rather numerous. Some are of a normal type, moderately coarse grained, the mica (variable in quantity) being generally biotite. Certain of these are slightly gneissoid in structure. More definitely foliated, almost certainly as a result of pressure, are some rather micaceous (biotite) granites. Yet more distinctly gneissic rocks occur, with a mineral banding as well as a foliation, in which pressure modification is generally to be noted. One group of these has a rather markedly different character; they are fine grained gneisses, modified by pressure (to which, however, the texture does not appear to be due), not rich in quartz, consisting mainly of felspar (orthoclase or microcline and plagioclase) and biotite, with a more or less definitely banded structure. They present a considerable resemblance to certain rocks found in the district about Blair Athol (Scotland), which Dr. H. Hicks, in consequence of their rather peculiar aspect, has named the "pepper and salt" gneisses. We find also a coarse granite, rather porphyritic in structure, and rendered gneissoid by pressure, which contains large red impure garnets, up to about ¾ in. in diameter. Similar garnets, but of smaller size, also occur in several varieties of granite and gneiss; one of these might almost be called a kinzigite, others are granulites (leptynites).

The compact acid igneous rocks are not numerous; but a rather remarkable series from the neighbourhood of the Golden Throne calls for a little notice. Some come from the moraine proceeding from the west foot of the mountain. These are compact, but show a schistose structure with slightly micaceous or talcose aspect, indicative of crushing. They are parti-coloured; a grey, varying from slightly to markedly greenish, being streaked, spotted, and blotched with a dull Indian red, small white specks showing in some of the patches. The texture of the lighter part under the microscope is

* T. G. Bonney and General C. A. McMahon, 'Quart. Jl. Geol. Soc.,' vol. 47 (1891), p. 497; E. Hill and T. G. Bonney, 'Quart. Jl. Geol. Soc.,' vol. 48 (1892), p. 145.

2 к 2

speckled, or somewhat fibrous, with indications of minute aggregate polarisation, this being most conspicuous when it makes an angle of 45° with the vibration planes of the crossed nicols. The fibrous mineral very closely resembles the so-called sericite of some porphyroids. Here and there are grains of quartz, decomposed and sometimes broken felspar crystals, and some dark reddish, flaky patches. The dark microscopic spots contain corroded grains of quartz, decomposed or partly corroded felspar crystals, and the same dark red flaky minerals in a crypto- to micro-crystalline matrix. In one rounded lump, at first sight very like a pebble, some grains of crystalline calcite are enclosed. The smaller patches, though varying in detail, present a general resemblance, and there can be little doubt that they are fragments of a devitrified acid igneous rock. In the absence of definite characters, it is difficult to speak positively as to the nature of the matrix, but most probably it was once a volcanic glass, which has since undergone micro-mineralogical change, mainly in consequence of pressure.*

Though the red patches occasionally look very like pebbles, it is more probable that they are due to a flow brecciation. If we are right in our inferences, these rocks of the Golden Throne indicate an outpouring of acid lavas prior to the mountain making. Other specimens from the same district are generally similar to the above-described, but present varietal differences, and a small specimen of an Indian red colour from *débris* on the Baltoro glacier is very probably a tuff, though the amount of crushing makes it difficult to be sure.

The crystalline schists include epidote-, Piedmontite-, and various mica-schists. The first of these very probably occurs as a band in a hornblende-schist, and a rock very similar to it may be found at more than one locality on the Lizard peninsula, in Cornwall. The second schist will be described more fully below. The third group contains several varieties, one of which will receive a separate notice. Of the rest, it may suffice to say that with one exception they are ordinary types; this, however, though a well known one, has sufficient interest to warrant a slightly fuller description. The rock, which comes from the Hunza Valley, between Gulmet and Tashot,† is a dark lead-coloured schist containing garnets. The latter, on microscopic examination, are found to be a pale reddish colour, sometimes fairly regular in outer form, cracked, granular in structure, and often containing a fair amount of dusky enclosures. These have a somewhat dendritic grouping; the angles which the tufts make one with another are such as to suggest relations with the process

---

* As has happened in many porphyroids (T. G. Bonney, 'Proc. Geol. Assoc.,' vol. 9, 1885, pp. 250—258).

† Many fragments of this rock were lying along the bottom and slopes of the valley. Multitudes of garnets were found a little higher up the valley.—W. M. C.

of crystal building. Also tubes or fibrous cracks are present, arranged generally at right angles to the faces of the garnet. Rather irregular crystalline grains of yellowish staurolite with many enclosures occur; also irregular grains of magnetite, and numerous little patchy flakes of brown mica. These are all set in a crystalline matrix, consisting of white mica and (apparently) granular quartz, with usually a considerable quantity of opacite (probably graphite), a few small tourmalines (strongly dichroic, changing from a light to a brownish or dull greenish tint), and some small rutiles. A similar schist comes from near Askole, and one without garnets, but in other respects like these, from the south flank of Crystal Peak. The chief interest of these garnet-bearing mica schists is their very close resemblance to schists in the Lepontine Alps,* as described by one of us, where the rock is a local variety of a dark micaceous schist, and it occurs, to his knowledge, at intervals for a distance of over 30 miles in a straight line along the chain.

With the mica schists we may mention, under the general name of sericite schists, several very much crushed rocks from Kamar nala, Mir, and the Dar Valley, Bagrot, and then pass on to a group of more or less calcareous schists, such as are developed in the Alps, and are there associated with quartz schists, green schists, and the aforesaid black garnet schists. In that chain they not unfrequently pass into crystalline limestones or dolomites, and rocks of this character also occur in Mr. Conway's collection. One or two contain malacolite, and some show distinct signs of having been affected by pressure.†

Passing on to the ordinary sedimentary rocks, we find a number of limestones, more or less impure, some containing fragments of other rocks, with schistose calcareous grits, besides argillites and slates, one or two of the latter resembling the slates of Llanberis (North Wales). A few of the specimens contain much crystalline material, so that it is difficult to decide whether they are very crushed dark schists, or slightly altered slates largely composed of detrital crystalline material. Rocks may be found in the Alps which present similar difficulties.

Sandstones, grits, and conglomerates occur; some of the gritty rocks show a cleavage, and certain near the Golden Throne probably contain volcanic materials. A conglomerate from Mapnun, in the Burzil Valley, contains a fragment of a quartz diorite, which obviously had been already modified by pressure when it was made into a pebble, indicating that in this mountain region, as in the Alps, earth move-

---

* T. G. Bonney, 'Quart. Jl. Geol. Soc.,' vol. 49 (1893), p. 105, &c. We are informed by Mr. G. Barrow, F.G.S., that a similar schist occurs in the Central Highlands of Scotland.—T. G. B.

. † T. G. Bonney, 'Geol. Mag.,' 1889, p. 483, and 1890, p. 536.

ments must have occurred long anterior to those which have produced the existing chain. Lastly, two partially altered sedimentary rocks are of some interest. The first, from a fallen fragment half-way between Samaiyar village and Strawberry Camp, on the left bank of the valley, is a blackish, compact, slightly-cleaved rock, not distinctly crystalline, in which are scattered several crystalline grains, the largest slightly more than one-eighth of an inch in diameter. This has one fairly well-marked cleavage, with a sub-vitreous, slightly oily lustre, and a second more imperfect, meeting it at an obtuse angle. The hardness seems to be slightly less than 5. Under the microscope the ground-mass is seen to consist of minute films of a sericitic mica mixed with a minute colourless mineral and granules of opacite and ferrite. In this are scattered larger irregular grains and plates of a black mineral, with raggedly outlined flakes of biotite, containing much of the ground-mass, some prisms (probably rutile), and two or three specimens of a larger mineral (probably the same species as that already mentioned). The best defined has two cleavages, one more strongly developed than the other, meeting at an angle of about 76°, and extinction takes place at an angle of 30°, or a little less, with the former. The crystals exhibit a rather irregularly outlined prismatic form, the sides being roughly parallel with these cleavages, and are crowded with minute materials, apparently identical with the ground-mass. This presents a slight resemblance to that of the ottrelite rock of the Forges de la Commune, Ardennes, and of one or two schistose rocks from the Alps, which do not belong to the most ancient group. Both the biotite and the above-named mineral appear to have been formed *in situ* at a time when molecular movements were not easy. We are unable to identify the latter with any mineral known to us, but it somewhat recalls to mind the " knoten and prismen " from certain Jurassic rocks in the Lepontine Alps,* and even the couseranite from Vicdessos (Pyrenees). It does not seem to be tetragonal. We venture to suggest that it is a hydrous alumina-lime-silicate allied to the scapolite group. The matrix around the crystals is slightly coarser than elsewhere. Possibly the peculiarities in this rock may be the result of contact metamorphism. The other rock from near Trough Camp, on the right side of the névé, obviously contains rather angular fragments of white marble imbedded in a hard matrix, grey, speckled with dark green, in colour. The larger marble fragments are stained externally with limonite; many of the smaller are altogether brown. Microscopic examination shows these to consist alike of crystalline calcite, fairly coarse in the whiter parts, fine-grained in the iron-stained. Both structures are sometimes present in the same fragment, and their relations suggest that the fine-grained one comes from a

* T. G. Bonney, 'Quart. Jl. Geol, Soc.,' 1890, vol. 46, pp. 213—221, 232—236.

crushing of the coarser. The matrix has a sub-crystalline aspect, and is variable in character. In one part sub-angular grains appear to be, as it were, set in a matrix composed of small scales of mica (mostly white, but some green), and of a chalcedonic material. This condition closely resembles that described in some Huronian conglomerates, and probably results from the alteration of a felspathic grit. In other parts a large grain of quartz is occasionally seen, commonly fairly well rounded, and the ground-mass consists of a mixture, resembling that already described, of minute mica with felspathic-looking granules, enclosing larger crystals of green and brown mica and crystals of a second mineral. These are fairly developed, rather elongated prisms (varying from about 1 : 4 to 1 : 8) up to 0·04 in. in length, rather full of microlithic enclosures, very pale yellowish-green with transmitted light, with dichroism almost imperceptible, and moderately bright-coloured with crossed nicols. The mineral shows a rather irregular transverse cleavage with occasional hints of one parallel to the sides of the prism, and extinguishes straight or nearly so with the latter. Though it has a general resemblance to epidote, the cleavage parallel with the above-named sides is not so marked as usual. It is, however, more like this mineral than andalusite, with specimens of which we have compared it. The mica, which occurs in flakes, is dichroic, changing generally from a light straw colour to a brownish-green. It has formed after the epidote, and as it frequently borders the fragments of marble it may possibly be a lime-mica. It produces the impression that it is slowly eating up the ground-mass. Of other minerals present in parts of the slice, rutile, sometimes in geniculate twins, is rather abundant, and is included in both the epidote and the mica. From its mode of occurrence a derivative origin seems probable. A few granules of iron oxide, apparently limonite, occur, also a rounded grain of zircon, and one small crystal of brownish tourmaline, secondary in origin.

(2.) *Remarks on Certain Specimens of Interest.*

We proceed next to describe more particularly those rocks already mentioned which are more specially interesting. First of these are some rocks consisting almost wholly of hornblende.

Hornblendites.—One of them from a fallen block on the west side of the Astor Valley above Dashkin is a dark green, rather friable rock, which consists chiefly of hornblende, mostly in porphyritic crystals about ¾ inch long. More than one variety of this mineral appears on microscopic examination: one is blue-green (for rays along the *c* axis), and a yellower green (for direction at right angles); the other, in larger crystals, is strongly dichroic (*a* straw colour, *b* dark bronze-green, *c*

similar but slightly darker). In the latter, enclosures, probably hæmatite, are rather frequent, which apparently lie in the pinacoidal planes.* We find also some plagioclase felspar, a little pseudobrookite, rutile, and pyrite. The rock has suffered from pressure, which has caused locally the formation of a chlorite, and possibly of some secondary felspar.

Another specimen from the same locality seems to be a schistose form of a similar rock. It consists mainly of a blackish, glittering, fibrous hornblende, and thus is very dark green in colour. Its surfaces are somewhat slickensided and are covered with films of green copper ore. A few elongated grains of clear felspar or quartz appear on microscopic examination, but the slice consists almost entirely of hornblende in rather elongated prisms, with a very definite orientation. This is markedly dichroic, changing through bluish-green (c axis) to grass-green (b axis), or almost colourless (a axis); it contains occasionally small crystals of rutile, rather impure, arranged along the cleavage planes. A system of parallel planes extends continuously across the crystals of the slice whatever their orientation, roughly making angles of 70° and 110° with the foliation. Even in a grain of (?) quartz lines of enclosures seem to continue the direction of these planes. The rock is now a hornblende schist, but it was probably produced by pressure from one closely allied to a pyroxenite.

Piedmontite Schist.—We come next to specimens of Piedmontite schist, all from near the Gargo glacier. One from the left bank or moraine shows in a rich purple compact matrix a number of dull white spots, rather fragmental in aspect. These exhibit a slight orientation, and traces of divisional surfaces are perceptible, cutting this at an angle of rather more than 35°. Quartz, white mica, and piedmontite, the first being the most, the second the least, abundant, and some felspar, are the principal minerals shown in the slice. The quartz contains enclosures, generally minute but variable in size, occasionally with bubbles. The piedmontite occurs in more or less clustered grains or irregular short prisms. With ordinary transmitted light the mineral exhibits a great variety of tints, from rather dull pale orange or straw colour to a rich purplish-pink or strong orange-red, inclining sometimes to a burnt sienna, sometimes to a more purple hue. On testing for dichroism, we find in sections parallel to the orthodiagonal the colour changes from pale pink (parallel to b axis) to rich pink (c axis, as stated by Lévy), and in sections more or less transverse from pale yellow to burnt sienna, and in some sections from deep amber (a axis)† to a rich pink or slightly orange-purple.

---

* These might be similar to the enclosures in schillerised pyroxenes described by Professor Judd, which, however, consist of mixtures of limonite and other oxides. See 'Quart. Jl. Geol. Soc.,' 1885, vol. 41, pp. 379, 381, 384, &c.

† 'Les Minéraux des Roches,' p. 184.

The grains are apt to be irregular in external form, and seldom exhibit a perfect crystal outline; besides this they have generally a rather dusty look, as if they contained numerous small enclosures. We find also one or two grains of a mineral rather irregular in outline, which has two cleavages crossing at a large angle, and exhibits not very high polarisation tints. It is probably monoclinic or triclinic, and a secondary product. In parts of the slide crystalline granules of iron oxide (? hæmatite) are fairly abundant, and exhibit a somewhat streaky arrangement. Under the microscope the white spots of the rock consist almost wholly of crystalline quartz, and have a somewhat brecciated aspect. This suggests that the specimen may be from a vein, but the rest of the rock in structure more resembles a schist. There seem to be some slight indications of mechanical disturbance, but if this has occurred it has been followed by very considerable recrystallisation.

The next specimen (fig. 1) comes from a small boulder on the south bank of the stream flowing from the east, through the "maidan" of Gargo. This appears to be a rather compact and hard schist, which

Fig. 1.—Piedmontite Schist, near Gargo Glacier.

evidently contains a fair amount of white mica in very small scales, and is rather rich in piedmontite. At the first glance the slice exhibits a large number of crystals of piedmontite, similar to those already described, together with small garnets and two micas, one

colourless, the other brown, in little films, all scattered in a fairly glass-clear ground-mass; one or two grains of iron oxide and possibly of rutile occur. The crystals generally have a foliated arrangement, and are somewhat irregularly grouped, comparatively free lacunæ occurring here and there. The garnets are clear, and contain a few enclosures (? cavities); they usually occur in well-formed dodecahedra, and are about 0·002 inch in diameter. This is seldom and very slightly exceeded, but much smaller specimens are not rare. The white mica is less abundant where the garnets are common, and has a tendency to occur in larger crystals and group itself round the lacunæ. With crossed nicols the greater part of the ground-mass exhibits a rather minute mosaic structure, and is probably, at least to a considerable extent, secondary felspar. The larger interspaces prove to be in some cases aggregated granules of quartz, in others an almost water-clear felspar, cleavage planes and occasional twinning being perceptible The outline of the felspar is very irregular, and it is associated sometimes with granules like those above mentioned, as though it had been partly replaced by them. There can be no doubt that the piedmontite, the garnet, and possibly some of the white mica are of secondary origin. It is even doubtful whether all the larger grains of felspar and quartz are intact, for some contain more microliths than might have been anticipated. Calcite occurs locally in patches; in one place also a slightly granular mineral, giving bright tints with crossed nicols. The rock is now a piedmontite schist, but it is difficult to suggest what its original condition may have been, not improbably a fairly coarse-grained gneissoid or granitoid rock.

Another specimen from the left half of the Gargo glacier bears some resemblance to the preceding, but is less micaceous and paler in colour; also it contains a vein of quartz with some minute calcite. Even on microscopic examination the distinctions for the most part are only varietal, but broken felspars of considerable size are rather more conspicuous in the specimen, and the rock generally affords very marked indications of fracture and reconstitution. There is another specimen from the left side or moraine of the Gargo glacier (below the icefall), which has a general resemblance to the last but one, but has a slightly more slabby character.

These rocks have been compared with a specimen of the piedmontite schist of Japan, presented to one of us by the kindness of Professor Koto. This contains the characteristic mineral about as abundantly and as well developed as the Gargo specimens, but has more iron-glance (?), and more white mica, which sometimes seems to be slightly tinted by the manganese. The rock also is more definitely foliated.

Schist with Conspicuous Secondary Mica.—From Dasskaram Needle comes a pale grey, closely laminated silvery schist, markedly cal-

careous (effervescing with HCl), including minute dark grains. It contains numerous crystals of dark mica, as much as a quarter of an inch across, their outline being clearly defined and sometimes hexagonal. These commonly traverse the foliation planes at a high angle, and are unusually thick. Thus the edges, which project from a weathered silvery surface, have the form of oblong prisms, and somewhat resemble, as the colour varies from a very dark green to almost black, crystals of hornblende. Under the microscope the ground mass exhibits a foliated and slightly banded structure, and apparently consists in part of small grains; some seemingly calcite, while others —rather irregularly formed, partly free from enclosures, of a water-clear mineral, giving somewhat low polarisation tints and with a kind of zoned structure—are probably secondary felspars, which may retain traces of an original nucleus. The ground-mass contains also mica with, perhaps, a little chlorite. The larger crystals of mica exhibit a curious and interesting structure. They are generally a light brown in colour, but they assume a greener tint near to the outside. The former part is fairly dichroic, varying from a light, slightly greenish-brown to a fairly rich warm brown; but the greener parts are paler and not dichroic. The crystals are usually somewhat irregular in outline, but the cleavage is fairly good. In parts of the slide the mica appears in numerous small patches, mixed up with the ground-mass. These in some places seem to coalesce by

FIG. 2.—A Grain of Secondary Mica in Schist from Dasskaram Needle.

a gradual replacement of portions of the ground-mass, so as to form ultimately a kind of setting for the grains which remain. In other parts, however, though a considerable portion of the ground-mass persists, the characteristic cleavage of the mica can be readily detected,* its pleochroism being wanting, while a straight extinction is quite discernible. In these cases we have, as it were, the ghost of the mica, but commonly, as the mineral becomes more and more characteristic and pleochroic, the constituents of the ground-mass correspondingly disappear, until at last only few of them remain (fig. 2). In these, however, the original orientation is still preserved. Towards the edge of some of the grains the white mica, chlorite, &c., of the ground-mass seem, as it were, to pierce the brown mica. It is quite clear that this mineral has been formed after the production of the cleavage-foliation in the rock.† The manner of its occurrence suggests very strongly that its composition differs but slightly (except for the absence of CO_2) from that of an average sample of the ground-mass.

We are indebted to Mr. P. Williams for the following analysis of this mica, made in Professor Ramsay's laboratory at University College. As only a very small amount of the mineral could be spared for the purpose, he was placed under considerable difficulties, and found it necessary to compute the alkalies as potash. It must be also remembered that the crystals are rarely quite free from particles of ground-mass :—

SiO_2	30·3
Al_2O_3	24·7
Fe_2O_3	7·7
CaO	7·3
MgO	8·6
K_2O	14·0
H_2O	9·6
	102·2

The analysis corresponds generally with that of a hydrous mica, but has more potash (or alkalies) than is usual. It differs from biotite, which the mineral most resembles, in the higher percentage of alumina (in which it comes nearer to muscovite), and in the large amount of lime. So far as the mineral can be classified it appears to be a hydrous biotite, with a considerable part of the magnesia re-

---

* The cleavage locally is so strongly marked that at first sight one almost anticipates a twinning. The cleavage seems to be present, if one might say it, almost in advance of the mica.

† See T. G. Bonney, 'Quart. Jl. Geol. Soc.,' 1893, vol. 49, pp. 104—113, fig. 1, p. 107.

placed by lime. It is roughly intermediate between a lime-margarite and a meroxene described by Dr. Grubenmann.[*]

(3.) *Mineral or Vein Specimens.*

A considerable number of the specimens brought by Mr. Conway are vein-stones, or representative of minerals rather than of rocks. Quartz, of course, is common; calcite, dolomite, and chalybite not unfrequent. Besides these are found the following:—Anhydrite, actinolite, idocrase, noble serpentine, copiapite (probably from decomposition of pyrite), and almandine. There are numerous examples of common garnet, many of epidote and of tourmaline; also of pyrite, with chalcopyrite and other copper ores, usually in small amount. We have looked carefully for gold in the pyritiferous quartzose veins and other specimens, but have not detected any traces. One specimen alone seems to call for special notice—a pseudojade—and this perhaps is, more strictly speaking, a rock rather than a mineral, but we place it here since it was a fragment on a moraine (left half of the Baltoro Glacier), and nothing is known as to its origin. Its form is angular, being partly limited by joints; it is of a variably greenish colour, irregularly mottled by a pale yellowish tint. The hardness is about 6·5, the sp. gr. 3·26, and the general appearance suggests a jade, but it differs in microscopic character from the few specimens of that rock which we have examined.[†] A slice exhibits, in ordinary transmitted light, a ground mass of a very pale yellowish colour, containing irregular, dusty looking patches and lines, variable in their distribution. The parts freer from these enclosures are almost inert on polarised light, but contain at places a fibrous flaky mineral, extinguishing straight, and very faintly polarising with dull, olive-brown colours. This we find to correspond generally with the greener parts of the specimen. The more dusty intervals (those corresponding with the paler parts), exhibit, with crossed nicols, distinctly marked aggregates of very minute granules, and also a fibrous prismatic mineral, rather more brightly polarising, extinguishing at a fairly high angle, and having a somewhat matted arrangement: not improbably a pyroxene. There are some rather clustered granules and grains of a translucent brown mineral, seemingly isotropic, possibly a variety of garnet.

We have to thank Mr. P. Williams, of University College, for the following analysis, made in Professor Ramsay's laboratory.

---

[*] Quoted in ' Quart. Jl. Geol. Soc.,' vol. 46 (1890), p. 227.

[†] General C. A. McMahon has been good enough to examine the slide and to give us the benefit of his experience of Indian rocks, determining at the same time the specific gravity of the specimen and making a qualitative analysis.

$$
\begin{array}{ll}
SiO_2 & 38\cdot22 \\
Al_2O_3 & 13\cdot83 \\
Fe_2O_3 & 7\cdot81 \\
CaO & 25\cdot55 \\
MgO & 3\cdot73 \\
K_2O & 7\cdot07 \\
Na_2O & 2\cdot46 \\
\text{Loss at red heat} & 1\cdot89 \\
\hline
& 100\cdot56
\end{array}
$$

Microscopic examination, no less than chemical analysis, shows that this specimen cannot be referred to nephrite, and consists almost certainly of more than one mineral. But it is very difficult to ascertain what these may be. The microscope does not give much help, for it indicates an aggregate of ill-defined constituents, which sometimes recall the structures seen in examining the material named saussurite. The chemical analysis is remarkable for its richness in lime and alkalies (especially potash) and comparatively low percentages of silica and alumina. The general character of the rock suggests the possibility of jadeite being an important, if not the main constituent. But, according to Krenner,[*] the normal analysis of this mineral is $SiO_2 = 50\cdot23, Al_2O_3 = 25\cdot37, Na_2O = 15\cdot40$, and, though the actual analyses of specimens (doubtless being mixtures) have generally rather more silica, and less alumina and soda, with a little lime and protoxide of iron, still they do not correspond with the present one. Apart from the difficulty of the presence of so much potash, we should find, if we supposed the alkalies to be contained in jadeite, hardly any silica or alumina left to go with the lime and other protoxide constituents. Saussurite would account for some of the alkalies and of the lime, but it has nearly the same silica percentage as jadeite, and a rather higher one of alumina. Zoisite (proper) epidote, the scapolite group, and elæolite present, in each case, important differences. Certain of the constituents agree fairly well with one of the lime garnets.[†] The rock in which this occurs is said to be homogeneous, tough, with a rather waxy lustre, and a yellowish-white colour—hardness = 7, and sp. gr. = $3\cdot33 - 3\cdot64$. It gave, on analysis, $SiO_2 = 44\cdot85$; $Al_2O_3 = 10\cdot76$; $Fe_2O_3 = 3\cdot20$; $CaO = 34\cdot38$; $MgO = 5\cdot24$; loss by ignition, $1\cdot10$. Total, $99\cdot53$; and of this Dr. Hunt takes, for the garnet, $SiO_2 = 22\cdot69$; $Al_2O_3 = 10\cdot76$; $Fe_2O_3 = 3\cdot20$; $CaO = 21\cdot07$. Total, $57\cdot72$. Such a mineral as this, if present in considerable quantity, would leave in the Karakoram rock a fair amount of silica for the alkalies and remaining protoxide bases. A

* 'Neues Jahrb. f. Min.,' 1883, ii, p. 173.
† T. S. Hunt, 'Amer. Jour. Sci.,' vol. 27 (1859), p. 342.

mineral resembling a pyroxene seems to be present. On the whole, after consulting many analyses of rocks and minerals, we venture to suggest that this rock may be composed of a lime garnet,[*] a potash jadeite, a mineral of the scapolite group, and a little pyroxene (or, possibly, even wollastonite or pectolite). It is more probably a vein product, for the low percentage of alumina seems to exclude the possibility of a felspathic euphotide.

(4.) *Geographical Distribution of the Rocks.*

Mr. Conway's collection commences with some specimens from the Jhelam Valley below Barramula. These are a limestone and slates, not unlike some which occur in the Secondary series of the Alps. The next specimens are from Gurai, in the side valley north of the Tragbal Pass. These (fallen blocks) are granite and diorite. Advancing thence up the valley of the Kishanganga and the Burzil Valley, †phyllites,† a †conglomerate and then a †granite were collected, and fallen blocks, near Mapnun, furnished a slate and a serpentine. Descending from the Burzil pass towards the Astor Valley, †hornblende diorite and †chlorite schist were found; in fallen blocks diorites and a micaceous gneiss; and one water-rolled specimen of argillite. Near Astor, two varieties of gneiss were obtained from boulders. Below Astor, a †diorite on the west of the river, and apparently also on the east, and fallen blocks of hornblendite on the west, a †garnetiferous gneiss (near Parri), common as big boulders down the valley; and then †granulite and †fine-grained gneiss (these two abundant by the roadside). The strikes and dips recorded by Mr. Conway in some cases may be planes of jointing rather than of bedding, and in crystalline masses they are most probably to be reckoned as results of pressure. Down to this part of the Astor Valley, the strikes vary from 15° W. of N. to 10° E. of N., the dips varying from 30° eastward to vertical. From the lower part of the valley, and from below 'Hatu Pir come †micaceous gneisses, and †diorite at Ramghat. In the valley the strikes vary from N.N.E. to nearly N.E., the dips being on the south-eastern side from 30° to 45°, while below Hatu Pir the strike varies between 10° N. or S. of E., the dips being 33° on the southern side.

The first specimens brought by Mr. Conway from the valley of the Indus come from the neighbourhood of Bunji. They are †granite, hornblendite, decomposed diabase, and micaceous gneiss. The next specimens are representatives of the Bagrot Valley; its stream enters

---

[*] The constituents of the greater part of the rock are so feebly double-refracting that a fair quantity of an isotropic mineral, if disseminated in granules, might easily elude discovery.

† Specimens marked thus † were obtained *in situ.*

Gilgit (a tributary of the Indus), carring the drainage of a line of lofty peaks and their southern spurs, which curve round from Raki-pushi on the west to Emerald Peak on the east. From below Sinakar, in the lower part of the Bagrot Valley, comes a †hornblende schist (the general strike being nearly E.N.E., dip 55° northerly) and a †diorite. Hence to a fork in the valley near the foot of the Bagrot glacier, the specimens represent apparently †crushed gneiss, and diorites of more than one kind. One of these is said to extend far along the valley; others are common in the *débris*. Some strikes are recorded to easterly or east-north-easterly points, but the dips vary. The Bagrot glacier issues from a loop of peaks, and Mr. Conway re-marks that the mountains on the western side of the glacier as far as Rakipushi consist of hornblende rocks, like those of the Bagrot Valley. From the ridge he collected a †crushed gneiss, and from the Kamar nala beyond a crushed †quartzose mica schist. On the eastern side of the glacier were collected a calcareous †sillimanite schist and a †hornblende schist, the latter being pretty certainly a crushed doleritic rock, and not unlike some of the " grüner schiefer " of the Alps. From the glacier come a diorite, common in the left moraine, and a crushed mica schist. Passing up the eastern fork, Mr. Conway collected a †hornblende schist (or pressure-modified diorite), a †mica diorite, and some †sericite schists, before reaching the foot of the Burchi glacier which, descending from the north, joins the yet larger Gargo glacier. The specimens from near the former represent a crushed †calc-mica schist (*in situ* on the spur between the two glaciers) and (from the left moraine) a diorite, an impure limestone, and a phyllite, so that there must be here an infold of comparatively unaltered rock. From the other glacier a crushed †actinolitic schist occurs on the left bank of the valley beyond Gargo; yet further up on this side comes a †gneiss (crushed). The glacier was now crossed again to the slopes beneath Emerald Peak, on the ascent of which †sericite schist and †chlorite schist were obtained. The right moraine of the Gargo glacier furnishes sericite schists, the left moraine or left side, piedmonite schists, chlorite schist, diorite, hornblende schist or schistose diorite, calc-mica schist, and phyllite; from the more disturbed material is another diorite. Piedmontite schist also comes from a boulder farther down the valley on the left side. The exact locality where this interesting rock occurs *in situ* is not determined, but it is clearly somewhere in the buttresses of the Gargo Peaks. These are part of a huge spur which extends from the Emerald Peak to Dubanni. The strikes along the Gargo Valley from the fork are generally between 5° S. of E. to 7° S. of E.S.E., the dips on the south side of the valley and on a peak east of Gargo, are northward (from 40° to 80°) or vertical; on the north side of the valley they are southward 60°. On the hill above the icefall, how-

ever (left side), and on Emerald Peak, the strike is N. of E.N.E., the dip southerly 30° to 75°.

The next set are from the valley leading to the Gilgit river from Chalt. The geology of this region was investigated by Surgeon Captain Giles. Here Mr. Conway took but few specimens (†diorite and †hornblendite), and remarks that the rocks are similar to those of the Bagrot Valley. Approaching and passing Chalt, †crystalline limestone *in situ* and a †chloritic rock occur; the strike of these varies from 8° E. of S.E. to 13° S. of E., the dips being northerly from 50° to 85°. It is noted that much nearer Gilgit the strike of the rocks was E., with a varying dip, and that on going northward it bends round to be a little more nearly in the direction of the valley.

The next set of specimens represent the rocks between Gulmet and Shaiyar; they are †schistose calcareous grit, †fine-grained gneiss (both sides of the river), a †granulite, a †crystalline limestone, a †micaceous gneiss (at Shaiyar), and as loose specimens, garnets, common near the crystalline limestone, a felstone (Gulmet), and black garnet-schist (abundant). It is highly probable that we have in this region, as in parts of the Lepontine Alps, a series of gneissic rocks overlain by a group of crystalline schists, probably meta-morphosed sediments, over which comes a newer series of compara-tively unaltered strata. The strikes at this part are stated to be "parallel with the valley near Gulmet, the dip being 30° in a southerly direction"; above this they vary apparently from E.N.E. to E.S.E., the dips being generally on the southern side, from 20° to vertical.

In the Samaiyar Valley, below the glacier, are a †fine-grained gneiss, †granite (left side, west of camp), and, from fallen fragments on the same side, a schistose (?) dipyr rock, crystalline limestone, a mica schist (with some secondary mica), and a schistose grit (brought down abundantly by avalanches). The character of these rocks suggests the possibility that the granite is intrusive in the sedi-mentaries. The strikes in this part of the valley vary from 5° N. of N.E. to 7° S. of S.E., the dips being very high, generally from 85° to vertical. Along the Samaiyar glacier, on the left bank, is a †some-what micaceous gneiss. On the right, near Trough Camp, is a †mica-ceous conglomerate, which recalls some rocks of Huronian age in Canada. On the same side, near the east end of " Trough Saddle," is a †fine-grained gneiss (common down the left moraine of the glacier). The strikes below Trough Camp are between E.S.E. and 10° S. of S.E., dip southerly 55° to 80°, but at the east end of "Trough Saddle" the strike is nearly N.N.E., the dip vertical. After return-ing to the Nagyr Valley and ascending to Hopar, there come, beyond it, a †fine-grained gneiss, a †mica-diorite, and as loose specimens along the left side of the Nagyr Valley, and of the Bualtar glacier (apparently from the Crown of Dirran), diorites; from the medial

moraine of the glacier a granite, and from the right one a " number of rocks similar to those of the Bagrot Valley." Thus it would seem as if dioritic or doleritic rock or some modified form of either, extends over a large area along and east of the Nomal Valley north of the Gilgit River. The strike below Nagyr is 10° E. of S.E., dip northerly 75°, but south of Hopar the strikes vary from 5° S. of S.E., dip southerly 30° (recorded at more than one place), to 7° S. of E.S.E., dip southerly 50°. Along the Shallihuru glacier, ·at and above Mir Camp, come a †fine-grained gneiss, a †crushed mica schist, a †calcareous mica schist, a †limestone breccia (left bank), and from the Dasskaram Needle a †fine-grained gneiss, and a †mica schist with secondary mica (two varieties). A fine-grained gneiss is recorded as common in the Mir Moraine, and said by Mr. Conway to correspond with that on the " Trough Saddle." The strikes along the valley and on Dasskaram Needle vary from 5° S. of S.S.E. to 15° E. of S.E., the dips being south-westerly from 75° to 85°. From the Samaiyar Bar glacier come a crushed mica schist (left side), and a crushed calc schist (right moraine). The Rash ridge on the right bank of the Barpu glacier was climbed in more than one place. The eastern part consists of a †garnetiferous gneiss, †crystalline limestone, and a †mica diorite forming all the upper part of the ridge; the more western part of †garnetiferous gneiss and (?) †kinzigite,† micaceous gneiss, †banded gneiss, and a †diorite (" forming a thin vein at the top of the ridge "). The ridge must thus consist very largely of gneissic rocks, which, however, are pressure-modified igneous rocks. The strike is recorded as from 10° to 25° S. of S.E., the dips varying, those above Barpu Camp being southerly 30° to 60°.

In ascending by the long Hispar glacier to the pass of the same name the following rocks were collected : on Shukurri, near the foot of the glacier, a †fine-grained gneiss, also abundant in the moraine, and a †micaceous gneiss (left bank) ; and on the right (nearly three-fifths of the way up) a †granite, which, according to Mr. Conway, is common down the right moraine, and considerably higher up (camp by Hispar Snowfield) a †micaceous gneiss. The strikes vary from 2° E. of E.S.E. to 10° S. of E.S.E. ; the dips recorded from the lower part of the glacier, on the left bank, are vertical and 75° southerly, from the upper part, right bank, vertical and 60° northerly. The loose specimens are (in fallen blocks) from the right bank below Shukurri a micaceous gneiss, from the left, on Haigutum slopes, a banded gneiss (common); also a sandstone characteristic of the moraine of the Kero Lumba glacier, and from the right moraine a fine-grained gneiss (common). Evidently the rocks on either side of this huge Hispar glacier are crystalline, but an infolded mass of comparatively unaltered sedimentaries must exist somewhere among the peaks to the south.

In the descent from this pass over the Biafo glacier, a †gneissoid granite was found on the right side at Snow Lake Camp (the first halting place), the structure striking 10° N. of E., dipping 60° northerly, then at "Ogre's Camp" (on the same side), and again at Nambla Camp, near the lower end of the glacier, a †micaceous gneiss —in the former place striking 5° E. of S.E., dipping 80° on the southern side. From the left bank, at the foot of Latok glacier (eastern angle), comes a †granite, which, according to Mr. Conway, forms the bulk of the *débris*. Moraine specimens are: granite (the rock which "appears to form the needles"), fine-grained gneiss, and two specimens of crystallised actinolite (these, however, may be only vein products) (right side), and a slate (obtained a few yards from Ogre's Camp). Thus the crystalline rocks along both the Hispar and the Biafo glaciers appear to be generally granite or gneiss. The strikes recorded, both in these districts and further west along the Hunza, the Samaiyar, and the Nagyr valleys, seem to have a general tendency towards a point between S.E. and E., roughly corresponding with the direction of this part of the main chain.

From the valley of the Biaho, rather west of the entrance of that from the Biafo glacier, comes (near Askole) a †mica diorite, and as loose fragments, garnetiferous (?) quartzite, two varieties of garnet schist, one (water-worn) the black kind already mentioned, the other containing chlorite and green mica, and a fine-grained sandstone. The ascent to Skoro La pass (roughly south of Askole) gave a †micaceous gneiss. The specimens indicate that the rocks enclosing the Biafo glacier correspond generally with those on the west side of the Hispar Pass, and that the belt of sedimentaries, already noted as occurring somewhere among the mountains on the left bank of the Hispar glacier, possibly is prolonged into those on the right bank of the Biafo glacier.

A rather large valley descends into the Biaho Valley, carrying the drainage of the Punmah glacier, and separated from the one occupied by the Biafo glacier by a spur-like range of lofty mountains. The western side of the extremity of this contains †crystalline dolomite and a †fine-grained gneiss, the eastern side a †crystalline limestone, a †hornblende schist, a †fine-grained gneiss, and a †garnetiferous mica schist. The strike of the dolomite on the one side, and of the limestone on the other, is 11° S. of S.E., the dip being 40° towards the south-west. Ascending the Biaho Valley above the junction with that bringing the water from the Punmah glacier, Mr. Conway obtained, just at the angle between them, a †fine-grained gneiss, striking 5° E. of S.E., and dipping 70° on the south-westerly side. Near the foot of the Baltoro glacier, above the camp, comes a †granite and a sandstone from the blocks in the bed of the river. By this glacier on the north side were †granite, a †fine-grained gneiss

(into which apparently the granite is intrusive), a †crystalline lime-stone, the second striking 7° S. of S.S.E., dipping 10° on the western side, the third striking 10° N. of E., dipping 85° southerly, but with many contortions. On the south side are †granites, of which, accord-ing to Mr. Conway, the mountains rising on this side of the lower part of the glacier consist. The moraine on the right bank furnished an ordinary limestone, a black argillite, and a crystalline limestone; the medial one a fine-grained gneiss, a sandstone, a slaty (? felsitic) tuff, a limestone, a pseudo-jade (marked as rare), and three other speci-mens (of which the bulk of the moraine is said to consist), viz., a crushed gneiss, a sandstone, and a slate.

About this point a marked change takes place in the scenery. From the higher part of the Biafo glacier the mountains are charac-terised by needle-like forms; further to the east, though lofty, they are more rounded in outline. In this part Crystal Peak rises on the right bank of the Baltoro glacier. From its southern slope come (order uncertain) †fine-grained gneiss, a †calcitic quartz schist, a †dark mica schist, †dolomite, and †limestone (both crystalline), a †fine-grained gneiss, and another gneiss (crumpled). A specimen from the summit of Crystal Peak unfortunately consists mainly of crystal-lised quartz, but to this a little brecciated rock adheres, some frag-ments in which effervesce slightly and may be limestone. The mass of practically unaltered sedimentary rocks, of which the moraine has already given ample evidence, may therefore include the Crystal Peak. On the ascent to White Fan Pass, south-east of the same peak, were collected a †mica syenite, and a crystalline but fine-grained †white dolomite. A greyish †crystalline limestone occurs, it is said, apparently belonging to a mass of green rock, in which are thin seams of †noble serpentine. Halfway up to this pass the strike is recorded as S.E., the dip being 75° to the south-west. A diorite comes from the Angle Peak, *i.e.*, that which rises from the above-named mass west of the Godwin-Austen glacier.

The moraines from Gusherbrum give a sandstone and earthy lime-stones. The right bank of the Throne glacier †phyllite, †argillite, †limestone (these three being associated), †slate, and a †limestone breccia (this, however, might be a fault product). From the left bank of the same glacier (whether *in situ* is uncertain) a fine-grained gneiss, a granite, and a dolomite (the last is said also to occur on the Golden Throne). The strike in the mountains by the glacier is said to be 7° S. of E.S.E. (dip about vertical) and this continues all along the valley. The moraine starting from the western foot of Golden Throne affords sandstone, grits, and cal-careous grits (both schistose), limestones, and dolomite, and the *peculiar* felstone described above. Mr. Conway states that the last-named rock occurs on the mountain, and appears to form bands in the

schistose grits. On the Pioneer Peak the first point reached on the arête yielded schistose grits, one of which (a purple specimen with small pebbles) occurred again at the second peak, striking 5° E. of S., and dipping 35° to the east. It is evident that a considerable mass of sedimentary rock must be infolded in the range from Gusberbrum to Golden Throne.

The valley of the Indus from Parkutta to Tolti (roughly S.W. of the district last described) lies among alternating diorites and granites. Higher up, from Himis to the turn for Lama-yuru, or on either side of Leh, it is among †argillite and †slate (just like the redder slate of Llanberis); these are said by Mr. Conway to be "sandwiched" with granite.

Again and again throughout this district of the Himalayas, rocks bear evidence of severe pressure, the result of earth movements. Putting aside those which are either certainly or probably of igneous origin, we find three rather well-marked groups. One, fine-grained, speckled gneisses, very similar to those which occur on the south side of the Central Highlands of Scotland (*e.g.*, about Blair Athol); secondly, crystalline schists, limestones, and dolomites, doubtless metamorphosed sedimentaries, several of which are practically identical with specimens described by one of us from the Lepontine and Pennine Alps*; and, thirdly, a group of sedimentary rocks (not more than mechanically altered), which sometimes are very like the Mesozoic rocks of the Alps, though occasionally some have a rather more ancient aspect. With these the peculiar felstones of the Golden Throne appear to be associated, and in one or two places the presence of somewhat altered fragmental rocks is suggested. In all probability the history of the Karakoram-Himalaya region is very similar to that of the Alps. First is a great floor of crystalline rock, partly igneous, partly metamorphic (in the more strict sense of the word). On that was laid down (possibly with interruptions and marked intervening disturbances and denudations) a series of sedimentary rocks. This ended, all were affected by a process of folding on a gigantic scale and upreared into a mountain mass, which has been carved, by the usual agents of denudation, into peaks and valleys far surpassing in wildness and grandeur even those of the Alps.†

---

* T. G. Bonney, 'Quart. Jl. Geol. Soc.,' 1890, vol. 46, p. 187; and 1893, vol. 49, p. 89.

† The following altitudes are taken from Mr. Conway's volume: Dasskaram Needle, 17,660 feet; Rash Ridge, 15,930 feet; Hispar Pass, 17,650 feet; Crystal Peak, 19,400 feet; White Fan Saddle, 18,750 feet; Pioneer Peak (near Golden Throne), about 23,000 feet (at least 22,600 feet).

OBITUARY NOTICES OF FELLOWS DECEASED.

RICHARD OWEN was born at Lancaster on July 20, 1804. His father, whose name was also Richard, was engaged in business connected with the West Indies. His mother's name was Catherine Parrin. He was educated at the Grammar School at Lancaster (where one of his schoolfellows was W. Whewell, afterwards Master of Trinity), apprenticed to a surgeon of the name of Harrison in that town, and studied surgery at the County Hospital. No evidence can now be found for the statement which has appeared in many biographical notices that when a boy he went to sea as a midshipman, nor is there any that at a later period he had an intention to enter the medical service of the Navy, or applied for and obtained an appointment, as has also been stated.

In 1824 he matriculated at the University of Edinburgh, and had the good fortune to attend the anatomical course of Dr. Barclay, then approaching the close of a successful career as an extra-academical lecturer, whose teaching was of a very superior order to that of the third Monro, who, by virtue of hereditary influences, happened at that time to be the University Professor of Anatomy. In his work ' On the Nature of Limbs,' Owen refers to " the extensive knowledge of comparative anatomy possessed by my revered preceptor in anatomy, Dr. Barclay," and always spoke of him with affectionate regard.

He did not remain in Edinburgh to take his degree, but removed to St. Bartholomew's Hospital in London, and passed the examination for the membership of the Royal College of Surgeons on August 18, 1826.

His first published scientific works were in the direction of surgical pathology, being on encysted calculus of the urinary bladder and on the effects of ligature of the internal iliac artery for the cure of aneurism.

At St. Bartholomew's Hospital he soon attracted the attention of the celebrated Abernethy, through whose influence he obtained the appointment of Assistant Conservator to the Hunterian Museum of the Royal College of Surgeons. This was in 1827, and it caused him to abandon the prospect of private practice, to which he had begun to devote himself while living in Serle Street, Lincoln's Inn Fields, for the more congenial pursuit of comparative anatomy. The Conservator of

the Museum at that time was William Clift, John Hunter's last and most devoted pupil and assistant, under whose faithful guardianship the collection had been most carefully preserved during the long interval between the death of its founder and its transference to the custody of the College of Surgeons. From him, Owen early imbibed an enthusiastic reverence for his great master, which was continually augmented with the closer study of his collection and works, which now became the principal duty of his life. In 1830 and 1831 he visited Paris, where he attended the lectures of Cuvier and Geoffroy St. Hilaire, and worked in the dissecting rooms and public galleries of the Jardin des Plantes. In 1835 he married Clift's only daughter, Caroline, and in 1842 was associated with him as joint Conservator of the Museum. On Clift's retirement soon after, he became sole Conservator, with Mr. J. T. Quekett as Assistant.

He was appointed Hunterian Professor of Comparative Anatomy and Physiology in 1835, an office which he held until his retirement from the College in 1856, and from which he took the title of "Professor Owen," by which he was far more widely known than by the knightly addition of his later years.

Until the year 1852, when the Queen gave him the charming cottage called Sheen Lodge in Richmond Park, where he resided to the end of his life, he occupied small apartments within the building of the College of Surgeons; these, however inconvenient they might be in some respects, furnished him with unusual facilities for pursuing his work by night as well as day in the museum, dissecting rooms, and library, of that institution.

Owen's life of scientific activity may be divided into two periods, during each of which the nature of his work was determined to a considerable extent by the circumstances by which he was environed. Each of these periods embraces a term of very nearly thirty years. The first, from 1827 to 1856, was spent at the Royal College of Surgeons; the second, from 1856 to 1884, in the British Museum. It was in the first that he mainly made his great reputation as an anatomist, having utilised to the fullest possible extent the opportunities which were placed in his way by the care of the Hunterian Museum. For many years he worked in that institution under the happiest of auspices. From the routine and drudgery which always take up so large a portion of the time of a conscientious museum curator, he was relieved by the painstaking, methodical, William Clift; the far more gifted son-in-law being thus able to throw himself to his heart's content into the higher work of the office. This at first mainly consisted in the preparation of that monumental 'Descriptive and Illustrated Catalogue of the Physiological Series of Comparative Anatomy,' founded upon Hunter's preparations, largely added to by Owen himself, which was published in five quarto volumes between the

years 1833 and 1840. This work, which has been taken as a model for many other subsequently published catalogues, contains a minute description of nearly four thousand preparations. The labour involved in preparing it was greatly increased by the circumstance that the origin of a large number of them had not been preserved, and even the species of the animals from which they were derived had to be discovered by tedious researches among old documents, or by comparison with fresh dissections. It was mainly to aid him in this work that he engaged upon the long series of dissections of animals which died from time to time in the Gardens of the Zoological Society, the descriptions of which, as published in the Proceedings and Transactions of the Society, form a precious fund of information upon the comparative anatomy of the higher Vertebrates. The series commences with an account of the anatomy of an Orang Utan, which was communicated to the first scientific meeting of the Society, held on the evening of Tuesday, November 9, 1830, and was continued with descriptions of dissections of the Beaver, Suricate, Acouchy, Thibet Bear, Gannet, Crocodile, Armadillo, Seal, Kangaroo, Tapir, Toucan, Flamingo, Hyrax, Hornbill, Cheetah, Capybara, Pelican, Kinkajou, Wombat, Giraffe, Dugong, Apteryx, Wart-hog, Walrus, Great Ant-eater, and many others.

Among the many obscure subjects in anatomy and physiology on which he threw much light by his researches at this period were several connected with the generation, development, and structure of the Marsupialia and Monotrema, groups which always had great interest for him. It is a curious coincidence that his first paper communicated to the Royal Society (in 1832) "On the Mammary Glands of the *Ornithorhynchus paradoxus*" was one of a series which only terminated in almost the last which he offered to the same Society (in 1887), being a description of a newly excluded young of the same animal, published in the 'Proceedings,' vol. 42, p. 391.

On the completion of the 'Catalogue of the Physiological Series' his curatorial duties led him to undertake the catalogues of the osteological collections of recent and extinct forms. This task necessitated minute studies of the modifications of the skeleton in all vertebrated animals, and researches into their dentition, the latter being finally embodied in his great work on 'Odontography' (1840–45), in which he brought a vast amount of light out of what was previously chaotic in our knowledge of the subject, and cleared the way for all future work upon it. Although recent advances of knowledge have shown that there are difficulties in accepting the whole of Owen's system of homologies and notation of the teeth of Mammals, it was an immense improvement upon anything of the kind which existed before, and a considerable part of it seems likely to remain a permanent addition to our means of describing these

b 2

organs. The close study of the bones and teeth of existing animals was of extreme importance to him in his long continued and laborious researches into fossil forms; and, following in the footsteps of Cuvier, he fully appreciated and deeply profited by the dependence of the study of the living in elucidating the dead, and *vice versâ*. Perhaps the best example of this is to be seen in his elaborate memoir on the Mylodon, published in 1842, entitled 'Description of the Skeleton of an Extinct Gigantic Sloth (*Mylodon robustus*, Owen), with Observations on the Osteology, Natural Affinities, and Probable Habits of the Megatheroid Quadrupeds in General,' a masterpiece both of anatomical description and of reasoning and inference. A comparatively popular outcome of some of his work in this direction was the volume on 'British Fossil Mammals and Birds,' published in 1844–46, as a companion to the works of Yarrell, Bell, and others on the recent fauna of our island. He also wrote, assisted by Dr. S. P. Woodward, the article "Palæontology" for the 'Encyclopædia Britannica,' which, when afterwards published in a separate form, reached a second edition in 1861.

To this first period of his life belong the courses of Hunterian Lectures, given annually at the College of Surgeons, each year on a fresh subject, and each year the means of bringing before the world new and original discoveries which attracted, even fascinated, large audiences, and did much to foster an interest in the science among cultivated people of various classes and professions. They also added greatly to the scientific renown of the College in which they were given. To this period also belong the development and popularisation of those transcendental views of anatomy—the conception of creation according to types, and the construction of the Vertebrate archetype—views which had great attractions and even uses in their day, and which were accepted by many, at all events as working hypotheses around which facts could be marshalled, and out of which grew a methodical system of anatomical terminology, much of which has survived to the present time. The recognition of homology and its distinction from analogy, which was so strongly insisted on by Owen, marked a distinct advance in philosophical anatomy. These generalisations, first announced in lectures at the College of Surgeons, were afterwards embodied in two works: 'The Archetype and Homologies of the Vertebrate Skeleton' (1848) and 'The Nature of Limbs' (1849).

The contributions which Owen made to our knowledge of the structure of Invertebrate animals nearly all belong to the earlier period of his career, one of the most important being his admirable and exhaustive memoir on the Pearly Nautilus founded on the dissection of a specimen of this, at that time exceedingly rare, animal, sent to him in spirit by his friend Dr. George Bennett, of Sydney. This

was illustrated by carefully executed drawings by his own hand, and published in the year 1832, when he was only 27 years of age. The Cephalopoda continued to engage his attention, and the merits of a memoir on fossil Belemnites from the Oxford Clay, published in the ' Philosophical Transactions' in 1844, was the cause assigned for the award to him of the Royal Medal in 1846. He contributed the article "Cephalopoda," to the ' Cyclopœdia of Anatomy and Physiology' (1836), catalogued the extinct Cephalopoda in the Museum of the Royal College of Surgeons (1856), and wrote original papers on *Clavagella* (1834), *Trichina spiralis* (1835), *Linguatula* (1835), *Distoma* (1835), *Spondylus* (1838), *Euplectella* (1841), *Terebratula* (in the introduction to Davidson's classical ' Monograph of the British Fossil Brachiopods,' 1853), and many other subjects, including the well-known essay on " Parthenogenesis, or the Successive Production of Procreating Individuals from a Single Ovum " (1849).

In 1843 his ' Lectures on the Comparative Anatomy and Physiology of the Invertebrate Animals,' in the form of notes taken by his pupil Mr. W. White Cooper, appeared as a separate work. Of this, a second expanded and revised edition was published in 1855. By this time, as the Royal Society's ' Catalogue of Scientific Papers ' shows, he had been the author of as many as 250 separate scientific memoirs.

In 1856, when Owen had reached the zenith of his fame, and was recognised throughout Europe as the first anatomist of the day, a change came over his career. Difficulties with the governing body of the College of Surgeons, arising from his impatience at being required to perform what he considered the lower administrative duties of his office, caused him readily to take advantage of an offer from the Trustees of the British Museum to undertake a newly created post, that of Superintendent of the Natural History Departments of the Museum. It was thought that hitherto these departments, being under the direct control of a chief who had been invariably chosen from the literary side of the establishment, and whose title in fact was that of " Principal Librarian," had not obtained their due share of attention in the general and financial administration, and that if they were grouped together an placed under a strong administrator, who should be able to exercise influence in advocating their claims to consideration, and who should be responsible for their internal working, their relative position in the establishment would be improved. Owen was accordingly placed in this position, with a salary of £800 a year,* and bade farewell to the College of Surgeons, its museum, and its lectures. At the British

* It may be mentioned that he was already in receipt of a Civil List pension of £200 a year, accorded to him in consideration of his scientific work, mainly in the completion of the catalogue of the Hunterian Collections.

Museum, however, he encountered the difficulties which are nearly always experienced by an outsider suddenly imported into the midst of an existing establishment without any very well-defined position. The Principal Librarian, Panizzi, was a man of strong will and despotic character, and little disposed to share any of his authority with another. The heads of the departments, especially Dr. J. E. Gray, Keeper of Zoology, preferred to maintain the independence to which they were accustomed within their own sphere of action, and to have no intermediary between them and the Trustees, except the Principal Librarian, who though perhaps with little sympathy, had also, from lack of special knowledge, but little power of interference in detail. Hence Owen found himself in a situation the duties of which were little more than nominal, probably for him the best that could have been, as it gave his indomitable industry full play in the directions for which his talents were best fitted, and with the magnificent material in the collections of the Museum at his command, he set to work with great vigour upon a renewed series of researches, the results of which for many years taxed the resources of most of the scientific societies of London to publish. It followed from the nature of the materials that came most readily to his hand, and the smaller facilities for dissection now available than those afforded by the College of Surgeons, that his original work was henceforth mainly confined to osteology, and chiefly to that of extinct animals. The rich treasures of the palæontological department were explored, named and described, as were also the valuable additions which poured in from various parts of the world, attracted in many cases by Owen's great reputation. The long series of papers on the gigantic extinct Birds of New Zealand, begun in the year 1839, at the College of Surgeons, with the receipt of the fragment of a femur, upon which the first evidence of their existence was based, was now continued at intervals as fresh materials arrived. The Marsupials of Australia, the Edentates of South America, the Triassic Reptiles from South Africa, the *Archæopteryx* from Solenhofen, the Mesozoic Mammals from the Purbeck, the Aborigines of the Andaman Islands, the Cave remains, human and otherwise, of the South of France, the Cetacea of the Suffolk Crag, the Gorilla and other Anthropoid Apes, the Dodo, Great Auk, and *Chiromys*, and many other remarkable forms of animal life were all subjects of elaborate memoirs from his untiring pen. These were adorned in every case with a profusion of admirable illustrations, drawn as often as possible of the full size of nature. His contributions to the publications of the Palæontographical Society, mainly upon the extinct Reptiles of the British Isles, fill more than a thousand pages, and are illustrated by nearly three hundred plates.

He now also found leisure to perform the pious duty of vindicat-

ing the scientific reputation of his great predecessor, John Hunter, by arranging and revising for publication a large collection of precious manuscripts containing records of dissections of animals and observations and reflections upon numerous subjects connected with anatomy, physiology, and natural history in general. These were published in 1861, in two closely printed octavo volumes, entitled 'Essays and Observations in Natural History, Anatomy, Physiology, Psychology, and Geology, by John Hunter, being his Posthumous Papers on those subjects.' The original manuscripts had been destroyed by Sir Everard Home, in 1823, but fortunately not before William Clift had taken copies of the greater part of them, and it was from these copies that the work was compiled. Its publication shows that Hunter, while occupied with a large and anxious practice—in itself labour enough for an ordinary man— while cultivating with a passionate energy the sciences of physiology and pathology, while collecting and arranging a museum such as has never been formed before or since by a single individual, had also carefully recorded a series of dissections of different species of animals which, as his editor justly says, "if published *seriatim*, would not only have vied with the labours of Daubenton, as recorded in the 'Histoire Naturelle,' of Buffon, or with the 'Comparative Dissections' of Vicq d'Azyr, which are inserted in the early volumes of the 'Encyclopédie Méthodique' and the 'Mémoires de l'Académie Royale de France,' but would have exceeded them both together."

In 1866 were published the first and second volumes, and in 1868 the third volume, of Owen's own great book on the Anatomy and Physiology of the Vertebrates.

This is the most encyclopædic work on the subject accomplished by any one individual since Cuvier's ' Leçons d'Anatomie Comparée,' and contains an immense mass of information mainly based upon original observations and dissections. It is in fact a collection of nearly all his previous memoirs arranged in systematic order, generally in the very words in which they were originally written, and unfortunately sometimes without the revision which advances made in the subject by the labours of others would have rendered desirable. Very little of the classification adopted in this work, either the primary division of the Vertebrates into Hæmatocrya and Hæmatotherma, or the divisions into classes and sub-classes, has been accepted by other zoologists. The division of the Mammalia into four sub-classes of equivalent value, upheld by Owen, not only in this work, but in various other publications issued about the same time (Rede Lecture, &c.), founded upon cerebral characteristics, was especially open to criticism. Though the separation of the Monotremes and Marsupials from all the others as a distinct group

(Lyencephala) is capable of vindication, the three other sub-classes, Lissencephala, Gyrencephala, and Archencephala, grade so imperceptibly into each other that their distinction as sub-classes cannot be maintained. The proposed definition of the distinguishing characters of the brain of Man (Archencephala) from that of other Mammals gave rise to a somewhat acute controversy, the echoes of which reached beyond the realms of purely scientific literature. On the other hand, the radical distinction between the two groups of Ungulates, the odd-toed and the even-toed, first indicated by Cuvier, when treating of the fossil forms, was thoroughly worked out by Owen through every portion of their organisation, and remains as a solid contribution to a rational system of classification.

The chapter called " General Conclusions " at the end of the third volume is devoted to a summary of his views on the principal controverted biological questions of the day, especially in relation to the teaching of Darwin, just then coming into great prominence. Although from the peculiarly involved style of Owen's writing, especially upon these subjects, it is sometimes difficult to define his real opinions, it appears that before the publication of the ' Origin of Species,' he had " been led to recognise species as exemplifying the continuous operation of natural law, or secondary cause, and that not only successively but progressively." Darwin's special doctrine of " natural selection," however, he never appreciated, and his strong opposition to it caused him, though quite erroneously, to be looked upon by those outside the world of science as a supporter of the old-fashioned and then more " orthodox " view of special creation. His most distinct utterance upon this subject is contained in the following paragraph:—" So, being unable to accept the volitional hypothesis, or that of impulse from within, or the selective force exerted by outward circumstances, I deem an innate tendency to deviate from parental type, operating through periods of adequate duration, to be the most probable nature, or way of operation, of the secondary law, whereby species have been derived one from the other."—(*Op. cit.*, vol. 3, p. 807.)

His career as a lecturer did not entirely cease with his connexion with the College of Surgeons, as, by permission of the authorities of the Museum of Practical Geology in Jermyn Street, he gave several courses on the fossil remains of animals, open to the public, in the theatre of that institution, and he held in the years 1859, 1860, and 1861, in conjunction with his office at the British Museum, the Fullerian Professorship of Physiology in the Royal Institution. On the revival of the annual lecture on Sir Robert Rede's foundation in the University of Cambridge, in 1859, he was appointed to give the first, and took for his subject the Classification of the Mammalia. He also occasionally lectured at the Royal Institution on Friday

evenings, his last appearance there being on April 26, 1861, when he delivered the discourse "On the Scope and Appliances of a National Museum of Natural History," to be presently referred to. In April, 1862, he gave four lectures on Birds at the London Institution.

While at the College of Surgeons he had been a member of a Government Commission for enquiring into the health of the Metropolis; and subsequently (in 1849) of one on Smithfield and the other meat markets, in which he strongly advocated the entire suppression of intramural slaughter-houses, and the concomitant evil of the passage of droves of sheep and cattle through the streets of London. For the Great Exhibition of 1851 he was on the Preliminary Committee of Organisation, and he acted as Chairman of the Jury on raw materials, alimentary substances, &c., and published an elaborate report on their awards. He also delivered to the Society of Arts a lecture on "Raw Animal Products, and their Uses in Manufacture." Similar services were performed by him for the Exposition Universelle of Paris in 1858.

It has been already said that Owen took scarcely any part in the details of the administration of the British Museum, but one subject relating to that establishment did largely engage his attention from his first connexion with it. That the accommodation afforded by the rooms devoted to natural history in the Museum at Bloomsbury was painfully inadequate for the purpose was evident to him as well as to everyone else. Space must be obtained somewhere, even for the proper conservation and display of the existing collections, to say nothing of the vast additions that must be expected if the subject were to be represented in anything like the way in which it deserved to be in his eyes, and Owen in this respect had very large views. The scientific public, the officers of the Museum, and the Trustees were much divided as to whether it would be better to endeavour to obtain this space in the neighbourhood of the existing Museum, or to remove a portion of the collection to a totally distinct locality. After some apparent hesitation, Owen threw himself strongly on the side of those who took the latter view, being the one which seemed to him to have the best chance of leading to a successful result, and he strongly urged upon the Government, and upon the public generally, in annual Museum returns, lectures, and pamphlets, the desirability of the scheme. In his address as President of the Biological Section of the British Association at the York meeting in 1881, he has given a history of the part he took in promoting the building of the new museum at South Kensington, including his success in enlisting the sympathy of Mr. Gladstone, by whose powerful aid the difficulties and opposition with which the plan was met in Parliament were mainly overcome. His earlier views upon the subject are fully

explained in a small work entitled 'On the Extent and Aims of a National Museum of Natural History,' published in 1862, being an expansion of the lecture he gave at the Royal Institution in the previous year. Much controversy arose about this time as to the best principle of museum organization, Owen adhering to the old view of a public exhibition on a very extensive scale, while the greater number of naturalists of the time preferred the system of dividing the collections into a comparatively limited public exhibition, the bulk of the specimens being kept in a manner accessible only to the researches of advanced students. The Royal Commission on the Advancement of Science, of which the Duke of Devonshire was Chairman, investigated the subject fully, and reported (in 1874) in favour of the latter view; but in the new building at South Kensington there was, unfortunately, little provision made for carrying it out in a satisfactory manner.

As long ago as 1859, in one of his reports on the subject to the Trustees, Owen recommended that the new museum building, "besides giving the requisite accommodation to the several classes of natural history objects, as they had been by authority exhibited and arranged for public instruction and gratification, should also include a hall or exhibition space for a distinct department, adapted to convey an elementary knowledge of the subjects of all the divisions of natural history to the large proportion of public visitors not specially conversant with any of those subjects." The same idea, in a later publication, is thus described :—" One of the most popular and instructive features in a public collection of natural history would be an apartment devoted to the specimens selected to show type characters of the principal groups of organised and crystallised forms. This would constitute an epitome of natural history, and should convey to the eye, in the easiest way, an elementary knowledge of the sciences." In every modification which the plans of the new building underwent, a hall for the purpose indicated in the above passages formed a prominent feature, being in the later stages of the development of the building, called, for want of a better name, the " Index Museum." Though Owen gave the suggestion and designed the general plan of the hall, the arrangement of its contents was left to his successor to carry out.

In another part of his original scheme he was less successful. The lecture theatre which he had throughout urged with great pertinacity as a necessary accompaniment to a natural history museum was, as he says in the address referred to above, "erased from my plan, and the elementary courses of lectures remain for future fulfilment."

On several other important questions of museum arrangement, Owen allowed his views, even when essentially philosophical as well

as practical, to be overruled. As long ago as December, 1841, he submitted to the Museum Committee of the Royal College of Surgeons the question of incorporating in one catalogue and system of arrangement the fossil bones of extinct animals with the specimens of recent osteology, and shortly afterwards laid before the Committee a report pointing out the advantages of such a plan. Strangely enough, though receiving the formal approval of the Council, no steps were taken to carry it out as long as he was at the College. He returned to the question in reference to the arrangement of the new National Museum, and although no longer advocating so complete an incorporation of the two series, apparently in consideration of the interests of the division into " departments " which he found in existence there, he says " The Department of Zoology in such a museum should be so located as to afford the easiest transit from the specimens of existing to those of extinct animals. The geologist specially devoted to the study of the evidence of extinct vegetation ought, in like manner, to have means of comparing his fossils with the collections of recent plants."* Provision for such an arrangement is clearly indicated in all the early plans for the building in which the space for the different subjects is allocated, but not a trace of it remained in the final disposition of the contents of the Museum, as Owen left it in 1883.

Another essential feature of Owen's original plan, without which, he says, " No collection of zoology can be regarded as complete," is a gallery of physical ethnology, the size of which he estimated (in 1862) at 150 ft. in length by 50 ft. in width. It was to contain casts of the entire body, coloured after life, of characteristic parts, as the head and face, skeletons of every variety arranged side by side for facility of comparison, the brain preserved in spirit, showing its characteristic size and distinctive structures, &c. " The series of zoology," he says, " would lack its most important feature were the illustrations of the physical characters of the human race to be omitted."

An adequate exhibition of the Cetacea, both by means of stuffed specimens and skeletons, also always formed a prominent element in his demand for space. " Birds, shells, minerals," he wrote, " are to be seen in any museum ; but the largest, strangest, rarest specimens of the highest class of animals can only be studied in the galleries of a national one." And again: " If a national museum does not afford the naturalist the means of comparing the Cetacea, we never shall know anything about these most singular and anomalous animals."

When, however, the contents of the museum were finally arranged, nominally under his direction, physical anthropology was only repre-

* 'On the Extent and Aims of a National Museum of Natural History,' 2nd edit., 1862, p. 7.

sented by a few skeletons and skulls placed in a corner of the great gallery devoted to the osteology of the Mammalia, and the fine series of Cetacean skeletons could only be accommodated in a most unsuitable place for exhibition in a part of the basement not originally destined for any such purpose. The truth is that the division of the museum establishment into four distinct departments, each with its own head, left the "superintendent" practically powerless, and Owen's genius did not lie in the direction of such a reorganisation as might have been effected during the critical period of the removal of the collections from Bloomsbury and their installation in the new building. Advancing age, also, probably indisposed him to encounter the difficulties which inevitably arise from interference with time-honoured traditions. At length, at the close of the year 1883, being in his eightieth year, he asked to be relieved from the responsibilities of an office the duties of which he had practically ceased to perform.

The nine remaining years of his life were spent in peaceful retirement at Sheen Lodge, an ideal residence for one who had such a keen enjoyment of the charms of nature in every form, for, though so large a portion of his active life had been passed among dry bones, anatomical specimens, microscopes, and books, he retained a genuine love for out door natural history, and the sight of the deer and other animals in the park, the birds and insects in the garden, the trees, flowers, and varying aspects of the sky, filled him with enthusiastic admiration. He also had his library around him, and it is needless to say that the habit of strenuous work never deserted him till failing memory and bodily infirmity made it no longer possible to continue that flow of contributions to scientific literature which had never ceased during a period of sixty-two years, his first and last papers being dated respectively 1826 and 1888. His wife and only son had died some time before, but the son (who had held an appointment in the Foreign Office) left a widow and seven children, who, coming to reside with him at Sheen, completely relieved his latter days of the solitude in which they would otherwise have been passed. During the summer of 1892 his strength gradually failed, and he died on the 18th of December, literally of old age. In accordance with his own expressed desire, he was buried in the churchyard of Ham, near Richmond, in the same grave with his wife, a large and representative assemblage of men of science being present at the funeral ceremony.

It may be thought that the prodigious amount of work that Owen did in his special subjects would have left him no time for any other occupations or relaxations, but this was by no means the case. He was a great reader of poetry and romance, and could repeat by heart, even in his old age, page after page of Milton and other favourite authors, for he was gifted with a wonderful memory. For music he had a positive passion; in the most busy period of his life he might

constantly be seen at public concerts, listening with rapt attention, and in his earlier days was himself no mean vocalist, and acquired considerable proficiency in playing the violoncello. He was also a neat and careful draughtsman; the large number of anatomical sketches he left behind him testify to his industry in this direction. His handwriting was unusually clear and finished, considering the vast quantity of manuscript that flowed from his pen, for he rarely resorted to dictation or any labour-saving process. Only those who have had to clear out rooms, official or private, which have been long occupied by him can have any idea of the quantity of memoranda and extracts which he made with his own hand, and most of the books he was in the habit of using were filled with notes and comments.

Owen's was a very remarkable personality, both physically and mentally. He was tall and ungainly in figure, with massive head, lofty forehead, curiously round, prominent and expressive eyes, high cheek bones, large mouth and projecting chin, long, lank, dark hair, and during the greater part of his life, smooth-shaven face, and very florid complexion. Though in his general intercourse with others usually possessed of much of the ceremonial courtesy of the old school, and when in congenial society a delightful companion, owing to his unfailing flow of anecdote, considerable sense of humour, and strongly-developed faculty of imagination, he was not only an extremely adroit controversialist, but no man could say harder things of an adversary or rival. Unfortunately he was often engaged in controversy, a circumstance which led to a comparative isolation in his position among men who followed kindred pursuits, which was doubtless painful to himself as well as to others. It was this, combined with a certain inaptitude for ordinary business affairs, which was the cause of his never having been called to occupy several of the distinguished official positions in science to which his immense labours and brilliant talents would otherwise have fairly entitled him. Over the British Association he presided at the meeting at Leeds in 1858, and he had his full share of those honours and dignities to which a scientific man can aspire which involve no corresponding duties or responsibilities. He was made a C.B. in 1873, and a K.C.B. on his retirement from the Museum in 1884. He received the Prussian Order " Pour le Mérite " in 1851, the Cross of the French Legion of Honour in 1855, and was also decorated by the King of Italy with the Order of St. Maurice and St. Lazarus, and by the Emperor of Brazil with the Order of the Rose. He was chosen one of the eight foreign Associates of the Institute of France in 1859. The Universities of Oxford, Cambridge, and Dublin conferred upon him their honorary degrees, and he was an honorary or corresponding member of nearly every important scientific society in the world. The Geological Society presented him with the Wollaston Medal in 1838, and the

Royal College of Surgeons with its Honorary Gold Medal in 1883. He was the first to receive the gold medal established by the Linnean Society at the centenary meeting of that body in 1888. The Royal Society, of which he became a Fellow in December, 1834, and on the Council of which he served for five separate periods, awarded him one of the Royal Medals in 1846, and the Copley Medal in 1851.

<div style="text-align: right">W. H. F.</div>

Sir William Aitken was born at Dundee on April 23, 1825, and received his early education in the High School of that town. He commenced the study of medicine under his father, a medical man in Dundee, and by attendance in the wards of the Dundee Royal Infirmary. In November, 1842, he matriculated in the University of Edinburgh, where, after attending lectures in the faculty of arts, and having complied with the requirements of the medical curriculum, he took the degree of Doctor of Medicine in 1848, his thesis on a pathological subject on that occasion gaining for him a gold medal. He also became a Licentiate of the Royal College of Surgeons of Edinburgh in the same year. Thence he appears to have proceeded to the University of Glasgow as Demonstrator of Anatomy under Dr. Allen Thomson. This office he continued to fill in conjunction with that of Pathologist to the Royal Infirmary of Glasgow up to 1855. Here he laid the foundation of that knowledge of disease which procured for him the appointment as Pathologist to the Hospitals of the Bosphorus, which were then filled by sufferers from the army in the Crimea. In association with the late Dr. Lyon he published a report on the diseases of the Crimea, which appeared in a Blue-book in 1856, and it is, and always will be, a valuable work of reference in regard to the maladies which were so fatal to the troops in that campaign.

On the foundation of the Army Medical School, which commenced its existence in 1860 at Chatham (afterwards transferred to Netley), and was an outcome of the experience of the Crimean War, Dr. Aitken was made Professor of Pathology, an appointment for which his early training and matured experience in the military hospitals in the East peculiarly fitted him, and which his subsequent career at Netley has abundantly justified. This duty he continued to perform until April, 1892, when failing health compelled him to rest from work. His final resignation of the chair had been fixed for the close of the session in July, 1892; but renal disease, from which he had for some time suffered, to the profound regret of his colleagues and numerous friends, terminated his valuable life on June 25, 1892.

Of the value of Aitken's work at the Army Medical School, as well as to medicine generally, it would be difficult to speak too highly. As a teacher he was pre-eminently successful in his method of imparting

knowledge ; his reasoning was scientific and practical, his demonstra-
tions lucid and convincing, and he must be gratefully remembered by
hundreds of medical officers who owe much of their knowledge of
disease, its causes and results, to his teaching.

A friend and colleague of Dr. Aitken writes :—"In the *post-mortem*
room he was *facile princeps*. I never saw any one to compare with
him at work of this kind. It was a lesson none could forget to see
him conduct a *post-mortem* and hear his exposition of what he saw.
He had great powers of work, and was a student in his own way all
his life. His book held the field for many years as a student's text-
book." And, again, " He was scrupulously honest as a writer ; strove
always to give every man his due."

Aitken's services to medicine were not restricted to his work as a
teacher and examiner. He made many contributions of importance
to the literature of medicine, and to that branch of it which he had
made peculiarly his own—pathology. Up to the last he continued
his labours, and at the time of his last illness was engaged in the
publication of a descriptive catalogue of the Museum of Pathology
now located at Netley. It is to be hoped that some competent
successor will undertake to carry on and complete the work thus
unfortunately interrupted.

It is sufficient to name the chief of his writings to indicate the
debt due to this great pathologist, and to show how earnestly he
laboured to contribute his share of knowledge to the common stock.
The following are the best known :—

" On Inflammatory Effusions into the Substance of the Lungs as
modified by Contagious Fevers," 1849. (2) " Contributions to
Pathology." (3) " On the Pathology of the Diseases of the Troops in
the East during the Russian War, 1855–56," in conjunction with
Dr. R. D. Lyons. (4) " On the Diseases of the Troops in the East
during the Russian War, and on the Climate of Scutari, on the
Bosphorus," 1857. (5) "Medical History of War with Russia,"
1857. (6) " On the Persistent and Pernicious Influence of the
Residence in Bulgaria on the Subsequent Health of the British
Troops in the Crimea." (7) " On conducting *Post-mortem* Examina-
tions at Coroners' Inquests," 1857. (8, 9, 10) " On the Pathological
Connexions and Relations of Epidemic Diseases in Man and the
Lower Animals, with special reference to the relationship between
the health of man and the condition of his food," 1857. (11) " Ana-
lytical Review of the Transactions of the Medico-Chirurgical Society
of London, vol. xii," 1859. (12) " Critical and Analytical Review of
Recent Works on the Pathology of Vaccination, and its Protective
Influence from Small-pox," 1857. (13) " Analytical and Critical
Review of the First Decennium of the Pathological Society of
London," 1858. (14) " Handbook of the Science and Practice of

Medicine," 1858 [this has reached its seventh edition]. (15) " On the Growth of the Recruit and the Young Soldier" [now in its second edition]. (16) " On the Doctrine of Evolution in its Application to Pathology," 1885–86. (17) " On the Animal Alkaloids."

Aitken was a man of somewhat reserved and reticent speech, but what he said was pregnant with science and common-sense. He was of a most kindly, genial nature, loyal to his profession, devoted to his friends, and just to all. His personal character endeared him to every one. His frank, straightforward mode of expressing his opinions, tempered as they were by sound judgment and discretion, made him respected and esteemed, and contributed, in no small measure, to the formation of the reputation of one of that small but remarkable group of men to whom the great Army Medical School owes its rise, development, and success. Regretted universally by friends and colleagues, it is in the great School of Military Medicine, which owes him so much, that his loss will be most keenly felt.

His merits have not escaped some recognition. He was made a Fellow of the Royal Society in 1873. In 1887 he received the honour of knighthood. The Universities of Edinburgh and Glasgow, in 1888, conferred on him the degree of LL.D., whilst on the walls of the ante-room at Netley is an excellent portrait presented by his numerous friends, admirers, and pupils.

May his memory long continue to influence coming generations of medical officers in the School he loved so well !

J. F.

THOMAS HAWKSLEY, civil engineer, was born at Nottingham in 1807. He was educated as an architect and surveyor, but, having an inclination for mechanical pursuits, he studied diligently the sciences necessary to enable him to practise as a civil engineer, and with such success that in 1830 he undertook the construction of new waterworks for his native town. The knowledge and skill he exhibited in these works led to more practice in other districts, and in 1852 he removed his offices to London, where, before long, he took the highest rank in that branch of engineering having to do with water and gas supply, and with drainage and hydraulic works generally.

Mr. Hawksley was accustomed to say that he had constructed above 150 waterworks, many of the largest character; and that there were no important towns in Great Britain, and indeed very few great cities in the civilised world, in regard to which he had not been professionally consulted in some way or other. He is especially celebrated for having been the first to suggest and to carry into practice the system of "constant service" in water supply, which combined the most free and ample provision of water with the almost perfect

repression of waste, and with greatly improved sanitary conditions. The introduction of the system involved many difficulties and much opposition; but he always spoke of his success in it with great satisfaction and pride.

It must not be supposed that municipal engineering in the days of Mr. Hawksley's early practice meant simply building and mechanical operations. It involved often grave and novel considerations, and it was his merit to bring to bear upon them accurate scientific knowledge and careful study. The lucid and skilful manner in which he was in the habit of applying scientific principles to his professional practice was well known to engineers generally: "Mr. Hawksley's formulæ," "Mr. Hawksley's data," "Mr. Hawksley's general results," and so on, were continually adopted as familiar guides by his professional brethren, and were quoted as authorities against which there could be no appeal.

On one occasion he had to advise on the drainage of one of the largest towns in the kingdom, and a question arose involving some artificial hydraulic conditions of much greater magnitude than usual. Doubts were expressed as to the feasibility of his scheme, but Mr. Hawksley had a strong impression that the ordinary rules, based on comparatively small experiments, did not apply. He accordingly examined the question thoroughly, bringing to his aid certain recent hydraulic researches by eminent French mathematicians; and, with the help of the writer of this notice, he succeeded in showing the practicability of the plan by an amount of scientific evidence which, while it was perfectly new, was absolutely incontrovertible.

Mr. Hawksley was President of the Institution of Civil Engineers for the years 1872 and 1873, and of the Institution of Mechanical Engineers in 1876 and 1877.

In 1876 he was elected President of the National Association of Social Science, holding their meeting at Liverpool, when he gave an address especially remarkable for its happy application of statistics to sanitation. He was a clever and lucid writer, and his keen appreciation of scientific reasoning gave great weight to his opinions.

He was elected a Fellow of the Royal Society on the 6th of June, 1878, as being "especially distinguished for the application of Science to Hydraulic Engineering."

Mr. Hawksley was blessed with a constitution which prolonged his life and energy much beyond the ordinary lot of man. In the beginning of September, 1893, sixty-three years after his appointment as engineer to the Nottingham Waterworks, he undertook one of his customary tours of inspection of his works in progress in distant parts of England; but a fortnight afterwards he was attacked by a sudden and formidable disease, which his aged frame was not able to resist, and he died at his residence at Kensington on the 23rd.

W. P

JOHN TYNDALL was born at Leighlin Bridge, near Carlow, in Ireland, on the 21st of August, 1820, and the early years of his life, up to the age of 19, were spent in this village, where he received instruction in the school of one John Conwill, who seems to have been a man of somewhat original and independent character. Not much is known of the subjects taught to Tyndall in this school, but he certainly acquired there a very thorough knowledge of elementary mathematics and geometry. Classics did not form part of the curriculum; for, at the age of 27 he was still unacquainted with the Latin language.

On leaving school at the age of 19, he obtained an appointment as assistant in the division of the Ordnance Survey at Carlow. About two years later, Tyndall came to England and attached himself to a Manchester firm of railway engineers, by whom he was employed in levelling, surveying, and making out plans and estimates in accordance with the rules of the Board of Trade. In this occupation he seems to have spent about five or six years of his life, and the experience thus gained during the so-called railway mania, doubtless, contributed in no small degree to his subsequent love of pursuits which necessitated accuracy of measurement and logical reasoning.

In the year 1847, he became acquainted with the late George Edmondson, who, at that time, was endeavouring to introduce into a large private boys' school at Preston instruction in the elements of experimental science. In the spring of that year Mr. Edmondson undertook, at the instigation of the Socialists who were under the leadership of Robert Owen, to transform their abortive establishment, "Harmony Hall," into a school and agricultural college, which received the name of "Queenwood College." Here, for the first time in an English school, experimental science was practically taught in the laboratory and in the field, and Tyndall, although at considerable pecuniary loss to himself, was easily persuaded to become a teacher of mathematics and surveying in this new establishment, being chiefly influenced, as he himself declared, by the opportunity afforded him of working in a chemical laboratory.

Tyndall remained at Queenwood College, where he had an enthusiastic class of pupils who were greatly attached to him, until the autumn of 1848, when he accompanied the writer to Marburg, there to continue his study of chemistry in the laboratory of Professor Bunsen. He did not, however, confine his attention to chemistry, but attended also the classes of the professors of mathematics and physics. Indeed, by far the larger portion of his time, during his first year at Marburg, was spent in mathematical work.

In the year 1850 he graduated in the Philosophical Faculty, taking mathematics for his principal subject in *vivâ voce* examination, and, for the two subsidiary subjects, chemistry and physics. Before

admission to examination at Marburg, it is essential to present to the Faculty a memoir on some original investigation made by the candidate. Tyndall's dissertation was entitled, " Die Schraubenflaeche mit Geneigter Erzeugungs-Linie und die Bedingungen des Gleichgewichts für solche Schrauben," which shows that, at that time, Tyndall's knowledge of mathematics was superior to his acquirements in chemistry and physics.

Physical Researches.—About this time there came to Marburg, as extraordinary professor, an enthusiastic young physicist, afterwards well known as Professor Knoblauch, who exercised a profound influence upon Tyndall, and who was probably the main cause of the latter devoting himself, for the future, chiefly to physical science. It was in conjunction with Knoblauch that Tyndall made his first physical investigation, the results of which were published in the year 1850 with the title " On the Deportment of Crystallised Bodies between the Poles of a Magnet."

During the next thirty-three years Tyndall published 135 papers, or at the average rate of rather more than 4 per annum. From Marburg he migrated to Berlin, where he worked for about a year in Magnus's laboratory, continuing his researches on diamagnetism and magne-crystallic action, finally returning to England about the end of the year 1851 or the beginning of 1852. He took up his quarters again at Queenwood College, not as a teacher, but as a guest, awaiting the advent of some suitable appointment. At this time there was no physical laboratory in England, and consequently no chair of experimental physics. There was, it is true, a professor of physics at Owens College, Manchester, but the chair was occupied by a Cambridge wrangler, who, though an able mathematician, probably never made an experiment in his life. Tyndall had to wait until 1853, having in the meantime been an unsuccessful candidate for a professorship at Toronto.

On February 11th, 1853, he delivered, at the Royal Institution, his first public lecture " On the Influence of Material Aggregation upon the Manifestation of Force." This lecture, although of such an abstruse character, took his audience—mostly popular as it was—by storm. It concluded with the following graceful tribute to Faraday : —" This evening's discourse is, in some measure, connected with this locality ; and, thinking thus; am led to inquire wherein the true value of a scientific discovery consists ? Not in its immediate results alone, but in the prospect which it opens to intellectual activity, in the hopes that it excites, in the vigour which it awakens. The discovery which led to the results brought before you to-night was of this character. That magnet (pointing to the large electro-magnet at the Royal Institution) was the physical birthplace of these results ; and if they possess any value they are to be regarded as the returning

d 2

xx

crumbs of that bread which, in 1846, was cast so liberally upon the waters. I rejoice, ladies and gentlemen, in the opportunity here afforded me of offering my tribute to the greatest worker of the age, and of laying some of the blossoms of that prolific tree which he planted at the feet of the great discoverer of diamagnetism."

This phenomenal success with such a critical audience at once established Tyndall's reputation as a clear and powerful expositor of experimental science; and, in the following July, he was unanimously elected Professor of Natural Philosophy in the Royal Institution. It was in the physical laboratory of this Institution that the whole of Tyndall's subsequent work was performed, in so far as it was not work involving the personal observation of natural phenomena in the Swiss Alps and elsewhere; for, although he occupied the chair of physics in the Government School of Mines for several years, no laboratory was provided for him or his pupils in that Institution.

The following is Tyndall's own account of his first lecture given in his "Faraday as a Discoverer":—"In December, 1851, after I had quitted Germany, Dr. Bence Jones went to the Prussian capital to see the celebrated experiments of Du Bois Reymond; and influenced, I suppose, by what he heard, he afterwards invited me to give a Friday evening discourse at the Royal Institution. I consented, not without fear and trembling, for the Royal Institution was to me a kind of dragon's den, where tact and strength would be necessary to save me from destruction. On February 11th, 1853, the discourse was given, and it ended happily. I allude to these things, that I may mention that, though my aim and object in that lecture was to subvert the notions both of Faraday and Plücker, and to establish, in opposition to their views, what I regarded as the truth, it was very far from producing in Faraday either enmity or anger. At the conclusion of the lecture he quitted his accustomed seat, crossed the theatre to the corner into which I had shrunk, shook me by the hand, and brought me back to the table."

To return to Tyndall's first physical paper, published as a joint investigation by Knoblauch and himself:—by employing a method proposed by Dove, they examined the optical properties of crystals and found that these optical qualities went hand in hand with their magnetic observations. For a long time, these experiments led to the discovery of no fact of importance; but at length, the observers met with various crystals whose deportment could not be brought under the laws of magne-crystallic action as announced by Plücker. They also discovered cases which led them to imagine that this magne-crystallic action was by no means independent, as alleged, of the magnetism or diamagnetism of the mass of the crystal. In short, the more they worked at the subject the more clearly was it revealed to them, that the deportment of crystals in the magnetic

field was due, not to a force previously unknown, but to a modification of the known forces of magnetism and diamagnetism by crystalline aggregation. They found, for instance, that whilst Iceland spar, which had been adduced by Plücker and experimented on by Faraday, was, according to the law of Plücker, axially repelled by a magnet, it was only necessary to substitute, in whole or in part, ferrous carbonate for calcic carbonate, thus changing the magnetic but not the optical character of the crystal, to cause the axis to be attracted. They proved that the deportment of magnetic crystals is exactly antithetical to that of diamagnetic crystals isomorphous with the magnetic crystals, and showed this to be a general law. In all cases, the line which in a diamagnetic crystal set equatorially, always set itself in an isomorphous crystal axially. It was, moreover, shown that by mechanical compression other bodies were also made to imitate Iceland spar. The results of these experiments were published in the 'Philosophical Magazine' and in 'Poggendorff's Annalen,' and Tyndall subsequently, and apart from Knoblauch, continued these investigations in the laboratory of Magnus. The results and the conclusions drawn from them which form the first section of Tyndall's experimental researches, have never been called in question.

The great work of Tyndall's life, however, was not performed in the domain of magnetism, but in that of heat. Already, in the year 1852, he was experimenting on the transmission of heat through organic structures, and in October of that year he sent his first paper to the Royal Society, entitled "On Molecular Influences. Part I. Transmission of Heat through Organic Structures." As an illustration of the leisurely way in which such papers were treated in those days, this was not read until the 6th of January in the following year, and did not appear in the 'Transactions' until the year 1854, a year after it was read. The paper deals with the transmission of heat through wood, and the author expresses the laws of molecular action which he deduces from his experiments as follows:—1. At all the points not situate in the centre of the tree, wood possesses three unequal axes of calorific conduction, which are at right angles to each other. The first and principal axis is parallel to the fibre of the wood. The second and intermediate axis is perpendicular to the fibre and to the ligneous layers; while the third and least axis is perpendicular to the fibre and parallel to the layers. 2. Wood possesses three axes of cohesion which coincide with the axes of calorific conduction—the greatest with the greatest, and the least with the least. 3. Wood possesses three axes of fluid permeability which coincide with those of calorific conduction—the greatest with the greatest, and the least with the least.

These researches on the transmission of heat through organic structures were not afterwards continued, as Tyndall's attention was

soon after diverted from conduction to radiation; and his investigations on the action of gases and vapours upon radiant heat, continued for twelve years, constitute, by reason both of the experimental skill exhibited in their prosecution and the importance of the results obtained, the crowning achievement of his life. The first indication of the commencement of this work was given in a Friday evening lecture, delivered in the Royal Institution on the 10th June, 1859, " On the Transmission of Heat of different Qualities through Gases of different Kinds." At this lecture the apparatus used throughout his remaining investigations, with some modifications, was introduced to his audience. It consisted of a tube having its ends stopped airtight by polished plates of rock-salt. This tube could be attached to an air-pump and exhausted, so that any required gas or vapour could be admitted into it. A thermo-electric pile being placed at one end of the tube and a source of heat at the other, the needle of an extremely sensitive galvanometer connected with the pile was deflected. After it had come to rest, the air was pumped from the tube and the needle was carefully observed, to see whether the removal of the air had any influence on the transmission of the heat. No such influence showed itself, the needle remaining perfectly steady. A similar result was obtained when hydrogen gas was used instead of air.

It now occurred to the experimenter to increase the sensitiveness of his apparatus by the use of a differential galvanometer. Under the influence of two sources of heat, one of which was caused to pass through the experimental tube, the astatic needle of the galvanometer was brought to zero by two powerful currents, which exactly neutralised each other. A few strokes of the air-pump were now sufficient to make the current from the thermo-pile at the end of the tube to predominate over its antagonist by 40° or 50°. On re-admitting the air the needle again fell to zero, thus proving beyond doubt that the air within the tube intercepted a portion of the radiant heat, the source of heat being one at a temperature at about 300° C. Instead of a differential galvanometer and two thermopiles, Tyndall afterwards used only one pile with the two sources of heat operating upon its opposite faces. The same method was applied to other gases, with most remarkable results, gases being found to differ amongst themselves with regard to their action on radiant heat as much as liquids and solids do. Some gases he found bearing the same relation to others that alum does to rock-salt. He found transparent and dry coal-gas to be exceedingly powerful in cutting off the radiant heat from a source at about 300° C., but when the lime light was placed at one end of the tube and the rays concentrated by a convex lens were sent through the tube, having previously been caused to pass through a thin layer of water, the coal-gas had no power to absorb the *luminous* heat thus transmitted through it. He drew from these

experiments the conclusion that planets, even at a great distance from the sun, might have atmospheres of such a character as to maintain upon their surfaces sufficient solar heat for the maintenance of life, such as we know it on the surface of our earth.

Tyndall's first paper communicated to the Royal Society on this subject was received on May 26, 1859. This was, however, only a preliminary note, and his first formal paper on the investigation formed the subject of the Bakerian Lecture delivered on the 7th February, 1861. In this lecture he enumerated the enormous difficulties he had to contend with in devising methods by which trustworthy results could be obtained. He relates how, for seven weeks, he worked from eight to ten hours daily, and had to abandon all the results as liable to certain errors. It was only after much labour and many failures that he constructed an apparatus which yielded consonant and trustworthy numbers. Shortly summarised, the results of this classical investigation may be thus stated:—1. Elementary gases scarcely absorb any perceptible amount of radiant heat. 2. All compound gases absorb proportions varying directly with the complexity of their molecules. Thus the vapour of ether was found to absorb, for equal volumes at maximum density, 100 times the quantity of radiant heat intercepted by the vapour of carbonic disulphide. The molecule of carbonic disulphide vapour contains only 3 atoms, whilst that of ether contains no less than 15. Nevertheless, the quality of the atoms constituting the molecule has also a profound influence upon the absorptive power. Thus, carbonic acid contains in its molecule the same number of atoms as carbonic disulphide, but at a tension of 1·2 in. its absorption is represented by the number 37, whilst the vapour of bisulphide of carbon at a tension of only 1 in. is represented by the number 62. Again, ethylic borate, which contains in its molecule no less than 25 atoms, has an absorptive coefficient, at only 0·1 in. tension, represented by the number 620.

Of all the molecules experimented upon, boric ethylate was the most complex and exercised the most powerful absorptive effect upon radiant heat from a source at 100° C. Whilst elementary and difficultly liquifiable gases exercise, as already stated, a scarcely sensible absorptive effect, easily liquifiable elementary gases and vapours, like those of chlorine and bromine, exert a very sensible action. Thus, whilst oxygen, nitrogen, and hydrogen are represented by the absorption coefficient of unity, chlorine is represented by the number 60, and bromine vapour, at the same tension, by 160. Compound molecules, though no more complex than elementary ones, exert a much more powerful absorptive action; thus bromine and hydrobromic acid both contain only 2 atoms in their molecules, nevertheless the absorptive coefficient of hydrobromic acid is more than six times as great as that of bromine.

In this paper, Tyndall also studied the radiation of heat by gases, and found that oxygen, hydrogen, and nitrogen are practically incapable of radiating heat from a source of comparatively low temperature, whilst the radiating power of four compound gases is expressed by the following numbers :—

Carbonic oxide 12
Carbonic anhydride 18
Nitrous oxide 29
Olefiant gas.............. 53

Their radiative powers follow precisely the same order as their powers of absorption. He then proceeds to discuss the theoretical bearings of his experimental results. He draws attention to the enormous difference in behaviour towards radiant heat exhibited by mechanical mixtures of gases as compared with the same gases chemically combined. Thus hydrogen and nitrogen when mixed together in the proportion of 1 vol. of nitrogen to 3 vols. of hydrogen, produce a scarcely perceptible absorptive effect; whilst, when chemically united in the form of ammonia, they produce an enormous effect. Again, oxygen and hydrogen which, when mixed in their electrolytic proportion, show scarcely sensible action, when chemically combined in the form of aqueous vapour, exert a powerful action. So also with oxygen and nitrogen, which, when mixed, as in our atmosphere, both absorb and radiate feebly, when united as nitrous oxide, have their powers vastly augmented. Atmospheric air, freed from moisture and carbonic anhydride, and at a tension of 5 inches, did not effect an absorption equivalent to more than one-fifth of a degree of the differential galvanometer; whilst nitrous oxide of the same tension effected an absorption equivalent to 51°. Hence the absorption by nitrous oxide at this tension is about 250 times that of air. In like manner the absorption by carbonic oxide of this tension is nearly 100 times that of oxygen alone; the absorption of carbonic anhydride being about 150 times that of oxygen; whilst the absorption by olefiant gas of this tension is 1000 times that of its constituent hydrogen. But even the enormous action last mentioned was surpassed by the vapour of many volatile liquids possessing greater atomic complexity.

Tyndall visualised to himself the cause of this enormous difference. He considered that the compound molecules present broad sides to the ether, while the simple or elementary molecules do not; but, in consequence of these differences, the ether must swell into billows when the former are moved, while it merely trembles into ripples when the latter are agitated. In the interception of motion also, the former, other things being equal, must be far more influential than the latter.

Now, besides presenting broader sides to the ether, the association *of atoms* to form groups must, as a general rule, render their motion

through the ether more sluggish, and tend to bring the periods of oscillation into isochronism with the slow undulations of obscure heat, thus enabling the molecules to absorb more effectually such rays as have been made use of in his experiments. He concluded, however, that an agreement in period alone is not sufficient to cause absorption and radiation; but, in addition to this, the molecules must be so constituted as to furnish *points d'appui* to the ether. He remarks that the heat of contact is accepted with extreme freedom by rock salt, but a plate of this substance once heated requires a great length of time to cool. This effect is explained by the experiments of Balfour Stewart, which prove that the radiative power of heated rock-salt is extremely feeble. Periodicity, Tyndall remarks, can have no influence here, for the ether is capable of accepting and transmitting impulses of all periods, and the fact that rock-salt requires more time to cool than alum simply proves that the molecules of the former glide through the ether with comparatively smaller resistance, and thus continue moving for a longer time; while those of the latter, being extremely complex in comparison with rock-salt, present broad sides to the ether and speedily communicate to it the motion which manifests itself as heat. This power of gliding through still ether, possessed by the rock-salt molecules must, of course, enable the moving ether to glide round them, and no coincidence of period could, he thought, make such a body a powerful absorber.

Tyndall extended these experiments to the effect of odours on the absorption of radiant heat. He experimented upon the perfumes arising from patchouli, sandal wood, geranium, oil of cloves, otto of roses, bergamot, lavender, lemon, nearoli, portugal, thyme, rosemary, oil of laurel, cassia, camomile flowers, spikenard, aniseed, and, lastly, musk. Calling the absorptive power of the mixed nitrogen and oxygen of atmospheric air unity, the smallest absorption, namely, that of patchouli, was found to be 30; whilst the odour of cassia was 109, and that of aniseed 372. The most surprising result, however, was obtained with musk. It is well known that this substance goes on emitting its odour for months or even years without any perceptible loss of weight; yet, when it was placed in a small glass tube, and dry air was passed over it in the experimental tube, the inconceivably small amount of this odour gave an absorption expressed in one experiment by 74 and in a second by 72. Several kinds of tea treated in the same manner produced absorptions which varied between 20 and 28.

Ozone was also submitted to the same test, and was found to have an enormously greater absorptive power than ordinary oxygen. Electrolytic oxygen, which could only contain a small percentage of ozone, was found to have 126 times the absorptive power of ordinary oxygen. This result is extremely surprising in view of the univer-

sally received constitution of the molecules of oxygen and ozone, the molecule of ordinary oxygen containing 2 atoms, whilst the molecule of ozone contains only three.

Whilst Tyndall was pursuing these researches in London, Magnus was engaged in conducting a similar investigation in Berlin. The general agreement between the results of these two able experimenters was, as might be expected, very close. In one important respect, however, there was a striking divergence. This was in regard to the action of aqueous vapour upon radiant heat, Magnus having found that aqueous vapour had little or no action, whilst Tyndall found it to be a very powerful absorbent of the heat rays of low refrangibility. A long controversy ensued, each experimenter appeared to have full confidence in his own results, and the opinions of others were consequently far from unanimous until a paper by Tyndall, published in the ' Proceedings of the Royal Society ' in 1881, and entitled " Action of an Intermittent Beam of Radiant Heat upon Gaseous Matter," finally decided the point, and proved in a startling manner that Tyndall was right. In this paper he describes his repetition of the ingenious experiments of Mr. Graham Bell, wherein musical sounds were obtained through the action of an intermittent beam of light on solid bodies. Entertaining the opinion that these singular sounds were caused by changes of temperature producing corresponding changes of shape and volume in the bodies impinged upon by the beam, Tyndall argued that if this be the case, and if gases and vapours really absorb radiant heat, they ought to produce sounds more intense than those obtainable from solids; and it seemed to him plain, moreover, that by this new method many of his previous results might be brought to an independent test. Highly diathermanous bodies, he reasoned, would produce faint sounds, while highly athermanous bodies would produce loud sounds; the strength of the sound being, in a sense, the measure of the absorption. The source of the intermittent beam was a Siemens lamp connected with a dynamo machine in the front of which was placed a rotating disk. The result shall be related in Tyndall's own words.

" Sulphuric ether, formic ether, and acetic ether, being placed in bulbous flasks, their vapours were soon diffused in the air above the liquid. On placing these flasks, whose bottoms only were covered by the liquid, behind the rotating disk so that the intermittent beam passed through the vapour, loud musical tones were in each case obtained. These are known to be the most highly absorbent vapours which my experiments revealed. Chloroform and bisulphide of carbon, on the other hand, are known to be least absorbent, the latter standing near the head of diathermanous vapours. The sounds extracted from these two substances were usually weak and sometimes barely audible, being more feeble with the bisulphide than with the

chloroform. With regard to the vapours of aniline, iodide of ethyl, iodide of methyl, and benzol, other things being equal, their power to produce musical tones appeared to be accurately expressed by their ability to absorb radiant heat." The dry elementary gases, hydrogen, nitrogen, and oxygen, produced a musical note so feeble as to be heard only with attention; but when these dry gases were displaced by carbonic anhydride, the sound was far louder than that obtained from any of the elementary gases. Ammonia gas produced a loud musical note. Now came the crucial test to be applied to aqueous vapour.

Obviously, if dry air and moist air produced practically the same slight effect in the intermittent beam, the conclusion of Magnus would be right, whilst if the moist air produced a much louder sound, the correctness of Tyndall's result would be clearly demonstrated. He says: " In this relation the vapour of water was that which interested me most, and as I could not hope that at ordinary temperature it existed in sufficient amount to produce audible tones, I heated a small quantity of water in a flask almost to its boiling point. Placed in the intermittent beam, I heard—I avow with delight—a powerful musical sound produced by the aqueous vapour. I placed the flask in cold water until its temperature was reduced from about 90° to 10° C., fully expecting that the sound would vanish at this temperature; but, notwithstanding the tenuity of the vapour, the sound extracted from it was not only distinct but loud. Three empty flasks, filled with ordinary air, were placed in a freezing mixture for a quarter of an hour. On being rapidly transferred to the intermittent beam, sounds much louder than those obtainable from dry air were produced." Thus was this controversy finally set at rest.

Interpolated between the magnetic and thermal investigations, or carried on simultaneously with them, were his researches on the physical properties of ice. These investigations were carried out partly in the laboratory of the Royal Institution, but chiefly during vacation rambles in Switzerland. They involved a vast amount of laborious observation and acute reasoning, but in the light of recent experiments, it would be rash to predict that the theory of fracture and regelation, founded by Tyndall upon Faraday's original experiments, will maintain its place as the true and only explanation of the motion of glaciers.

In connection with his glacier work stand Tyndall's frequent ascents of Mont Blanc and other Swiss mountains. In one of these, namely the ascent of Mont Blanc in August, 1859, the writer accompanied him. The expedition was undertaken by Tyndall with the especial object of establishing several self-registering thermometric stations between Chamounix and the summit of the mountain.

Unfortunately the whole of these stations were swept away by avalanches during the following winter, except the one on the summit, which was seen to be intact next summer by the only mountaineer who made the ascent during that extremely unfavourable season. Probably this gentleman was too much occupied in admiring the grandeur of the surrounding scene to think of the importance of an observation of the minimum winter temperature at this great elevation. At all events he neglected to read off the self-registering instruments, and thus the expedition, so far as thermometric observations are concerned, was abortive. Nevertheless, it was not in other respects altogether unrewarded, as certain remarkable physiological and physical effects were observed during our stay of twenty-two hours on the summit of the mountain.

Almost immediately after arriving there, Tyndall became ill; he complained of headache, a burning sensation in the brain, and general lassitude, and expressed his belief that he was about to be seriously unwell. Scarcely half an hour had elapsed before all the guides and porters, nine in number, who had remained at the summit, complained loudly of headache, and expressed a strong desire to lie down and rest. Accordingly the erection of our tent was at once proceeded with. About 12 ft. below the summit of the ridge, and on its south side, a circular level plateau, about 10 ft. in diameter, was excavated in the snow, so as to form a level floor for the tent, the setting up of which did not occupy more than half an hour. As soon as it was ready, we were all glad to creep into it, the sun having become shrouded with fleecy clouds, which at once transformed the hitherto pleasing temperature into the piercing cold of a severe winter. The north wind had also increased in force, filling the air with clouds of snow blown from the terminal ridge of the mountain, and rendering exposure outside the tent by no means pleasant.

The cold blast of the north wind was not the only reason why the interior of our tent was so welcome, the general lassitude that had seized upon us all rendering lying down, even upon a bed of hard snow, a matter of urgent necessity. The indisposition of the whole party continued to increase; especially was this the case with Tyndall, who complained of fever, excessive thirst, and intense pain in the head. His pulse kept up to 100, but this was less alarming than the other symptoms, since the writer's own kept steadily at 120, although he was comparatively well during the first four hours of his sojourn upon the summit. Then a general lassitude stole over him also accompanied by headache.

Tea was the only liquid which was acceptable to us during the whole time of our stay on the summit. We had wine and brandy in abundance, but no one desired them; even champagne had a nauseous taste, and was far less acceptable than tea. For solid food there was

no desire; the writer ate only 2 oz. of bread on the summit of the mountain, and that quite in opposition to the will of the stomach. This distaste for food was common to the whole party. During the night, a thermometer inside the tent in which eleven people were closely packed, never sank below −1° C., although the temperature outside was as low as −17° C. The indisposition of the whole party continued, but there was little or no vomiting; and the prominent symptoms of mountain sickness seemed to be headache, with excessive lassitude and unwillingness to use the slightest physical, or even mental, exertion. The pulse was rapid but without any fever, except in the case of Tyndall, who continued alarmingly ill during the night. Snow wrapped up in a cloth and applied to his forehead and temples gave him some relief, but his thirst was insatiable; and as ice would scarcely melt in the warmest part of the tent, it was rarely that anything but snow could be obtained for him. Most of the party slept four or five hours, but both of us remarked that the peculiarity of our position developed a species of selfishness amongst the men, like that sometimes observed in cases of shipwreck, and which manifested itself in symptoms of insubordination and general discontent. Before leaving the horizontal position in the morning, or making any exertion, the writer's pulse was found to be still steady at 120, though unaccompanied by any feeling of feverishness. There was nothing unusual in respiration, and no difficulty of breathing. In short, lying there on the floor of the tent, there was nothing in our sensations by which we could have known that the tent was not pitched at the level of the sea on a frosty morning; there was no sensation which rendered the great rarefaction of the air perceptible.

Tyndall, who was now rapidly recovering, superintended the erection and furnishing of the thermometer post, and afterwards experimented on the thermal effect of the sun's rays; whilst the writer occupied himself with the collection of samples of air for analysis, and with experiments in the tent on the rate of combustion of stearin candles, which he had undertaken, at Tyndall's request, in order to test the correctness of the following statement made by Le Conte in Silliman's Journal of Science and Art. " Thus, a variety of well established facts concur in fortifying the conclusions to which we are led by à priori reasoning, namely, that the process of combustion is retarded by the diminution of the density of the air, whilst it is accelerated by its condensation." A comparison of the results obtained by burning these six candles for one hour at Chamounix, and for the same time on the summit of the mountain, completely refuted this statement; the amount of stearin consumed under the two widely different barometric pressures, was practically the same.

Another, and entirely unexpected, phenomenon, however, revealed itself to the writer in the course of these experiments. The candles

burning in the subdued light of the tent obviously gave a comparatively small amount of light; the lower and blue portion of the flame, which under ordinary circumstances scarcely rises to within a quarter of an inch of the apex of the wick, now extended to the height of an eighth of an inch above the cotton, thus greatly reducing the volume of the luminous portion of the flame. These experiments were repeated, on returning to England, in artificially rarefied atmospheres, and led to the discovery of the law that the diminution in illuminating power is directly proportional to the diminution of atmospheric pressure.

With the exception of one or two of the porters, all the party felt a marked diminution in the symptoms of mountain sickness after 8 A.M. The rate of pulsation regularly decreased during the descent, notwithstanding the violent muscular exertion. After remaining steadily at 120 during the 22 hours spent on the summit, that of the writer dropped to 100 in the corridor, 80 on the Grand Plateau, and to 56 at Chamounix, his normal pulse-rate being 60.

Biological Researches.—About the year 1875, Tyndall became interested in the question of spontaneous generation, which at that time was exciting a considerable amount of attention, especially in the medical profession. Pasteur had pronounced spontaneous generation a chimera, and expressed his undoubting conviction that, this being so, it is possible to banish zymotic diseases from the earth. To the medical profession therefore, and through them to humanity at large, this question was one of the last importance. But the state of medical opinion about it at that time was extremely conflicting and unsatisfactory. With a view to the possible diminution or removal of this uncertainty, Tyndall determined to apply the exact methods of experimental physics to this difficult biological problem. He had a number of chambers or cases constructed, each with a glass front, its top, bottom, back, and sides being of wood. These chambers were so contrived that infusions of various kinds could be exposed to germless air after being boiled. He thus had these infusions exposed to an atmosphere of oxygen, nitrogen, carbonic anhydride, ammonia, aqueous vapour, and all the other gaseous matters which mingle more or less with the air of a great city. He had them moreover "untortured" by calcination, and unchanged even by filtration or manipulation of any kind, for the air was rendered germless by subsidence. The question which he set himself to answer was this :—" Can air thus retaining all its gaseous mixtures but self-cleaned from mechanically suspended matter, produce putrefaction?" To this question both the animal and vegetable worlds gave him a decided negative. Among vegetables, experiments were made with hay, turnips, tea, coffee, and hops, and were repeated in various ways with both acid and alkaline infusions. Among animal substances he experimented with beef,

mutton, hare, rabbit, kidney, liver, fowl, pheasant, grouse, haddock, sole, salmon, cod, turbot, mullet, herring, whiting, eel, and oysters. The result was that infusions of these substances, exposed to temperatures varying from 27° C. to 32° C. in these germless atmospheres, in no single instance underwent putrefaction or developed the slightest amount of bacterial life. On the other hand, infusions of the same substances, exposed to the common air of the Royal Institution laboratory, all fell into putrefaction in the course of from 2 to 4 days; no matter where the infusions were placed, they infallibly became offensive in the end. The number of tubes containing infusions was multiplied until it reached 600, but not one of them escaped infection.

To detect the floating germs in the air, Tyndall employed a powerful beam of light from which the eye of the observer was carefully screened. "When the track of a parallel beam in dusty air," says Tyndall, "is looked at horizontally through a Nicol's prism, in a direction perpendicular to the beam, the longer diagonal of the prism being vertical, a considerable portion of the light from the finest portions of the suspended matter is extinguished. The coarser motes, on the other hand, flash out with greater force, because of the increased darkness of the space around them. It is among the finest ultra-microscopic particles that the matter potential as regards the development of bacterial life is to be sought." He was thus employing for the detection of suspended matter in air an instrument far more delicate than the microscope, and he reasons upon the results of his experiments as follows:—" But though they are beyond the reach of the microscope, the existence of these particles, foreign to the atmosphere, but floating in it, is as certain as if they could be felt between the fingers, or seen by the naked eye. Supposing them to augment in magnitude until they come, not only within the range of the microscope, but within range of the unaided senses; let it be assumed that our knowledge of them under these circumstances remains as defective as it is now—that we do not know whether they are germs, particles of dead organic dust, or particles of mineral matter. Suppose a vessel (say a flower-pot) to be at hand, filled with nutritious earth, with which we mix our unknown particles, and that, in forty-eight hours subsequently, buds and blades of well-defined cresses and grasses appear above the soil. Suppose the experiment, when repeated over and over again, to yield the same unvarying result. What would be our conclusion? Should we regard those living plants as the products of dead dust or mineral particles, or should we regard them as the offspring of living seeds? The reply is unavoidable. We should undoubtedly consider the experiment in the flower-pot as clearing up our pre-existing ignorance. We should regard the fact of their producing cresses and grasses as proof positive that the particles sown in the earth of the pot were the

seeds of the plants which have grown from them. It would be simply monstrous to conclude that they had been spontaneously generated. This reasoning applies, word for word, to the development of bacteria from that floating matter which the electric beam reveals in the air, and in the absence of which no bacterial life has been generated. There seems no flaw in this reasoning; and it is so simple as to render it unlikely that the notion of bacterial life developed from dead dust can ever gain currency among the members of a great scientific profession."

During the course of these experiments, Tyndall made the very important discovery of the necessity for the intermittent application of heat for the attainment of absolute sterility. He found that the spores of certain bacteria could resist a boiling temperature for five hours, although the fully-developed bacteria are killed by the application of the same temperature for a few minutes. Hence the now universal practice amongst bacteriologists of heating their infusions to the requisite temperature, for a few minutes on three consecutive days. The first heating destroys all the fully-developed organisms; before the second takes place, the remainder will, in all probability, have developed and be likewise destroyed; but certainly, by the heating on the third day, not a single germ will escape destruction.

It is not possible, within the space of an obituary notice, to do more than give a mere outline of the enormous amount of work accomplished during the thirty-three years of Tyndall's active life. Nothing has been said here of his most interesting work on acoustics, and many memoirs on isolated subjects have been entirely ignored.

As his colleague for six years in the Royal Institution, the writer had ample opportunity of judging of Tyndall's remarkable experimental skill and untiring perseverance in the search after truth. So long as any result was doubtful, no amount of labour was considered too great to eliminate all uncertainty. His cleverness in devising new forms of experiment for the interrogation of nature, was most striking; and he never allowed himself to trust hypothesis where appeal to experiment was possible.

In the year 1886, Dr. Tyndall's health entirely broke down, mainly through overwork, and the managers of the Royal Institution granted him a year's holiday; but, although this relief was of some benefit to his health, at the end of the year he felt compelled to resign his appointment. In accepting his resignation the managers, in their meeting in April, 1887, recorded the following resolution:—"The managers desire to record the expression of their deep regret that the state of Dr. Tyndall's health should have rendered necessary the resignation of his position of Professor of Natural Philosophy at the Royal Institution, and that it should have compelled the managers to accept that resignation. They also desire that there should be recorded

the expression of their thorough appreciation of the unremitting and most valuable services which, during the long period of 34 years, Dr. Tyndall has rendered to the Royal Institution in carrying out the duties of his office—services which not only have upheld and have advanced the position of the Royal Institution, but have benefited science and the world at large."

Professor Tyndall, on his withdrawal from the Institution, declined to receive any pension or pecuniary testimonial in recognition of his services; and, in severing his long connection with it, desired only to carry with him the friendly recollection and goodwill of the members. At the same meeting of managers, it was resolved unanimously that Dr. Tyndall be nominated for election at the next general monthly meeting, on Monday, May 9th, as Honorary Professor of Natural Philosophy; and he was so elected on that day. The managers also instituted, at the same time, an annual course of lectures to be called the Tyndall Lectures.

Dr. Tyndall held the post of Examiner in the Royal Military Colleges and in the University of London. In 1866, he succeeded Faraday as scientific adviser to the Trinity House, and occupied this position for 17 years. In 1872 he was invited to lecture in the United States, and realised a considerable sum of money from the large audiences attracted by his eloquence and experimental skill. The whole of this sum, amounting to between £6,000 and £7,000, he generously devoted to the encouragement of scientific training in the United States, dividing it equally between Columbia College in New York, Harvard College Boston, and the University of Pennsylvania at Philadelphia.

In 1876, he married Louisa, eldest daughter of the late Lord Claud Hamilton, and received, on the occasion of his marriage, a purse of 300 guineas from the members of the Royal Institution, and a medallion bust of himself, in marble, from his fellow members of the X—— Club.

Dr. Tyndall was elected a Fellow of the Royal Society in 1852. In 1853 a Royal Medal was awarded to him for his researches on magnecrystallic action. He also received the Rumford Medal, in 1864, for his researches on the absorption and radiation of heat by gases and vapours. He was D.C.L. (Oxon.), LL.D. (Cantab., Dubl., et Edin.), and an honorary member of a large number of learned societies at home and abroad.

The last years of his life, after his retirement from the Royal Institution, were clouded by repeated attacks of illness. In the autumn of 1893, his usual sojourn on the Bel Alp appeared to effect a substantial improvement in his health; but, almost immediately on his return, he had a serious relapse, from which he was gradually recovering, when, on the 4th of December, he died from the effects of an over-

dose of chloral accidentally administered to him in mistake for sulphate of magnesia. In the presence of a very large number of his friends and admirers, his remains were interred in Haslemere Churchyard on the 9th of December, the coffin bearing the following inscription:—"John Tyndall, died December 4th, 1893, aged 73 years."

<div align="right">E. F.</div>

Sir Samuel White Baker was born at Thorngrove, near Worcester, on the 8th June, 1821. He was the eldest son of Samuel Baker, of Lypiatt Park, Gloucester.

At the age of twenty-four he went to Ceylon, where he was engaged in agricultural pursuits in company with one of his brothers.

He has given an interesting account of life and sport in Ceylon in two works, which he afterwards published.

After quitting Ceylon, where it is understood his farming operations had not been a success, he was engaged for some time in Eastern Europe on the Ruschuk and Varna Railway.

In 1860, Speke and Grant set out from Zanzibar, commissioned by the Royal Geographical Society of London to follow up the discovery of the Victoria Lake and trace the Nile should it be found to be connected with that Lake. Baker determined to go at his own expense by way of Cairo, in order to meet his friends, and, if possible, render them the help of which they would stand in need. Setting out in 1861, he ascended the Nile, and was fortunate in meeting Speke and Grant at Gondokoro, thus enabling them to complete their journey, while he, aided by indications given him by these travellers, pressed south and discovered the Albert Nyanza, through which the Nile was found to flow.

On Baker's return to Europe he received, in recognition of his services, the honour of knighthood. He was also awarded for his geographical discoveries, the Gold Medal of the Royal Geographical Society and that of Paris, and was elected an Honorary M.A. of Cambridge, where he afterwards was Rede Lecturer in 1874.

In the year 1870 he returned to Egypt in the service of the Khedive, he ascended the Nile to Gondokoro in command of a well-equipped Egyptian force, and was for two years engaged in establishing the claims of Egypt to dominions on the Upper Nile. For this he was made a Pasha and Major-General in the Turkish service.

The remainder of his life was spent in foreign travel and at his home at Sandford Orleigh, near Newton Abbot, where he died December 30th, 1893. He became a F.R.S. in 1869.

<div align="right">J. K.</div>

ERRATUM.

Page 210, line 7 from bottom, *for* 20° 30′, *read* 23° 30′.

END OF FIFTY-FIFTH VOLUME.